

SERVICE MANUAL

11001 M

For the Brown Type 113
Mechanical Potentiometer
and
Resistance Thermometer



MINNEAPOLIS-HONEYWELL REGULATOR CO.

Industrial Division

PHILADELPHIA 44, PA.

THE BROWN INSTRUMENT COMPANY

PHILADELPHIA, PA.

A DIVISION OF

MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

Installation - Operation - Maintenance INSTRUCTION

Number **11001M** Issue **3**

SERVICE MANUAL FOR THE BROWN TYPE 113
MECHANICAL POTENTIOMETER AND RESISTANCE THERMOMETER

CONTENTS

Section 1353	Principles of Operation
Section 1354	Mechanical Operation of Single Record Potentiometer
Section 1355	Mechanical Operation of Multiple Point Print Hammer Potentiometer
Section 1356	Mechanical Operation of Multiple Point Print Wheel Potentiometer
Section 1357	Principles of Operation of Control Mechanisms
Section 1358	Description of and Data on Component Parts of Type 113 Mechanical Potentiometer
Section 1359	Mechanical Adjustments and Corrective Data
Section 1360	Electrical Adjustments and Corrective Data
Section 1361	Control Adjustments and Corrective Data
Section 1362	Maintenance
Section 1309	Lubrication
Section 1137	Temperature-Millivolt Equivalents
Section 9112	Temperature-Resistance Equivalents
Section 1046	Temperature-Millivolt Equivalents for the Brown Radiamatic

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Diagrams _____

Other
Instructions _____

Files _____

PRINCIPLES OF OPERATION OF THE
BROWN POTENTIOMETER TYPE INSTRUMENTS
BALANCING MECHANISM

A close study of the information contained in this service manual will enable the operator to obtain the best possible service from this type of instrument.

A. ELECTRICAL OPERATION

A potentiometer consists of a calibrated slidewire resistor through which a measured or standard current is passed, thus providing a calibrated voltage drop across the slidewire. A portion of this voltage determined by the position of the slidewire contactor, is opposed to the voltage generated by a thermocouple or radiation pyrometer. When these two voltages are equal the position of the slidewire contactors, which is connected to an indicating pointer, indicates the temperature of the thermocouple or radiation pyrometer on the slidewire scale, as this scale is graduated in degrees of temperature. This condition of equality or balance is determined by a D'Arsonval galvanometer which indicates balance or equality of voltage.

When the voltages are not equal, the self balancing potentiometer pyrometer recognizes this

condition of unbalance, determines its magnitude and direction, and corrects the slidewire contactor position, thus reducing the voltage difference to zero and indicating the temperature.

B. MECHANICAL OPERATION

An unbalance between the emf of the thermocouple circuit and the emf of the potentiometer circuit causes the galvanometer pointer to deflect away from the neutral or mechanical zero position.

The deflection of the galvanometer pointer is detected by the galvanometer step table. The elevation of the step table is transmitted through a series of levers to the step lever on the right-hand side plate. The step lever changes position of the slidewire contactor until the emf of the potentiometer circuit balances the emf of the thermocouple circuit.

The pen or print carriage is connected through a spiral shaft and spur gear to the slidewire and is moved across the scale to the correct temperature reading as the potentiometer circuit is brought to the balanced position.

REQUIREMENTS OF THE
DATA COLLECTION SYSTEM

The first requirement is that the data must be collected in a systematic manner. This means that the data must be collected in a way that allows for comparison and contrast between different groups or individuals.

The second requirement is that the data must be collected in a way that allows for the identification of patterns and trends. This means that the data must be collected in a way that allows for the identification of relationships between different variables.

The third requirement is that the data must be collected in a way that allows for the identification of individual differences. This means that the data must be collected in a way that allows for the identification of differences between individuals within a group.

The fourth requirement is that the data must be collected in a way that allows for the identification of changes over time. This means that the data must be collected in a way that allows for the identification of trends and patterns over a period of time.

The fifth requirement is that the data must be collected in a way that allows for the identification of the causes of different outcomes. This means that the data must be collected in a way that allows for the identification of the factors that lead to different results.

The sixth requirement is that the data must be collected in a way that allows for the identification of the effects of different interventions. This means that the data must be collected in a way that allows for the identification of the impact of different treatments or interventions.

The seventh requirement is that the data must be collected in a way that allows for the identification of the relationships between different variables. This means that the data must be collected in a way that allows for the identification of the connections between different factors.

The eighth requirement is that the data must be collected in a way that allows for the identification of the relationships between different groups or individuals. This means that the data must be collected in a way that allows for the identification of the connections between different people or groups.

MECHANICAL OPERATION OF THE
SINGLE RECORD POTENTIOMETER

The mechanical operation of the Single Record Instrument can be broken up into two parts: the balancing mechanism and the recording mechanism. These are described in detail as follows:

A. BALANCING MECHANISM

The hardened kidney cam, revolving once every 3.6 seconds, raises the step lever assembly. This allows the secondary pointer to take a position determined by the position of the galvanometer pointer on the galvanometer step table.

The height of the step table "C" Fig. 1354-1 is transmitted through the galvanometer table lever shaft "F" and galvanometer table lever "K" thus positioning the secondary pointer "D".

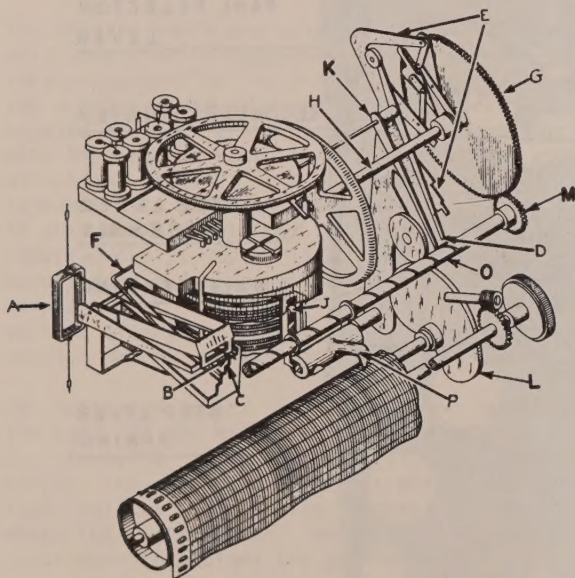


Fig. 1354-1 The Brown Operating Principle

A motor driven kidney cam "L" operates the above mechanism and drives the step lever "E" upward periodically. A spring then moves it downward until it is stopped by the secondary pointer "D".

As the step lever "E" starts to move downward, one of the pawls, fastened to the end of the step lever, is thrown into engagement with the large spur gear "G" by the pawl selector lever, which has been positioned by the secondary pointer "D".

The step lever "E" continues to move downward driving the large spur gear "G" until a step on the step lever contacts the secondary pointer "D".

Each step on the main step lever represents a movement of a definite number of teeth on the large spur gear; that is, 0, 1, 3, 10, 22, 44, and 80 teeth correspond to the neutral, 1st, 2nd, 3rd, 4th, 5th, and 6th steps on either side of neutral. The longest step gives the spur gear a movement of 80 teeth, which corresponds to an angular movement of that gear of about 120°.

The selector lever Fig. 1354-2 which clamps the secondary pointer just before the main step lever contacts it, does so on one of its two steps. The particular step selected depends upon whether the secondary pointer is above or below the neutral step on the step lever, which depends upon whether the galvanometer pointer is to the left or to the right of the neutral step on the step table, respectively.

The hub of the selector, where it is fastened on its bearings, carries the drive pawl spring, which positions one of the two drive pawls to cause that particular pawl to contact the large spur gear. This spring is positioned so that it will throw alternate pawls into engagement with the large spur gear when the secondary pointer is moved from 1 step below neutral to 1 step above neutral.

The two drive pawls shown in Fig. 1354-2 are driven by means of the upper and lower drive pawl links connected to the main step lever assembly. The step lever assembly is raised to its highest position by the kidney cam. At this point, the drive pawls are in their neutral position with the drive pawl spring mid-way between them. In rising, the main step lever pulls up on the selector lever which unclamps the secondary pointer. The secondary pointer drops back in time to be brought forward by the table lever. The table lever now moves the secondary pointer into position. The main step lever starts downward, releasing the selector lever, which clamps the secondary pointer due to the tension exerted by the pawl selector lever spring. In moving to the clamping position, the selector lever moves the drive pawl spring which causes one of the drive pawls to engage the large spur gear. The step lever assembly continuing its motion, drives the pawl which is

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1354

Page No. 2

in contact with the spur gear until stopped by the step lever contacting the secondary pointer.

The entire mechanism is spring driven and the motor merely resets the spring.

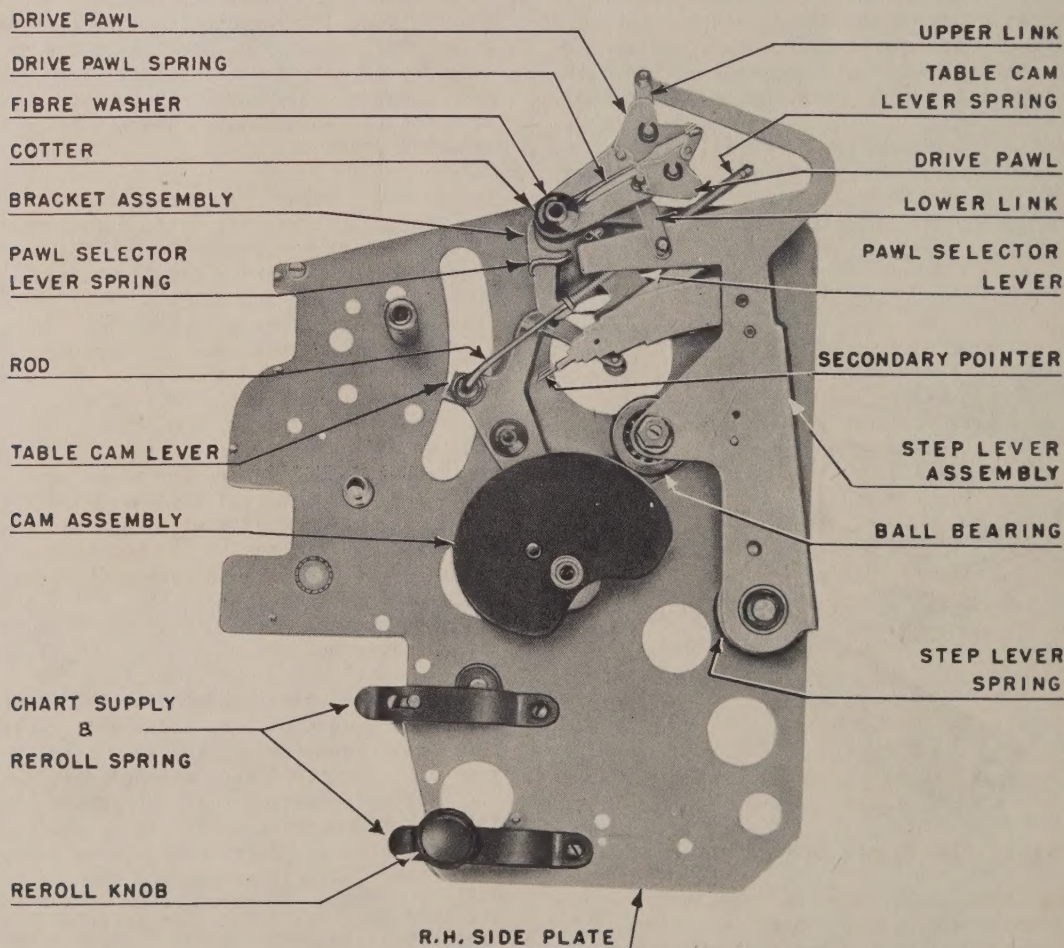


Figure 1354-2
Right-Hand Side Plate Single Record Instrument
Large Spur Gear Removed

One important feature of the main step lever spring drive is that the spring is amply strong to move the large spur gear under normal conditions. Under abnormal conditions, as when the pen reaches the end of the scale, the spring merely ceases to move the main step lever any further. Thus, it is not necessary to provide for slippage in the clutch, and the use of the positive pawl type clutch is made permissible.

In the initial part of the driving stroke of the main step lever, while the selector lever is being released, the pivot points on the pawls and their connecting links are in straight lines passing through their dead center position so that no motion is imparted to the pawls. Accordingly, the main step lever has to pass through relatively larger angular distances to advance the pawls and spur gear through the first few teeth than in the more advanced positions. A step lever motion of $5/16^\circ$ is required to advance the spur gear through one tooth, which moves the pen through 0.0093° .

The driving pawls are balanced on their axes and will remain out of engagement except when pushed into engagement by the drive pawl spring. During a driving stroke of the main step lever, the engaged pawl is drawn tightly into engagement with the gear on account of its geometrical construction, while on the return stroke the pawl releases its hold and goes out of engagement. If both pawls should be thrown into engagement simultaneously, as by hand, the drive spring merely does not move the main step lever on that stroke and at the end of the cycle both pawls will be disengaged and made ready for proper operation on the succeeding cycle.

The table cam lever, operated by the table cam (in back of the kidney cam), does two things in its cycle of operation. In its forward stroke (counter-clockwise) it moves the paper feed ratchet and in its backward stroke it moves the table lever, which pushes the step table down to unclamp the galvanometer pointer.

B. RECORDING MECHANISM

When the large spur gear rotates it causes the small 54-tooth spur gear or pen shaft gear to rotate. The pen shaft gear is fastened to a stainless steel spiral shaft which has a half-inch pitch helical V groove cut in it. This shaft drives the pen carriage in a positive manner. Exactly 22 turns of this spiral shaft moves the pen a full scale distance of eleven

inches. Thus, a driving pawl, operating upon the periphery of the large 236-tooth spur gear, drives through a total linear distance of about 66 inches to move the slidewire contactor $42\frac{1}{2}$ inches and the pen 11 inches. When the driving pawl moves the large gear through the distance of one tooth ($.056^\circ$ or nearly $1/16^\circ$), the pen is advanced through its smallest step of less than a hundredth of an inch ($.0093^\circ$). The largest pen step, corresponding to an advance of 80 teeth, is $.740^\circ$.

Figure 1354-3 shows the 6-step adjustable chart speed arm which governs the number of teeth taken on each stroke of the table cam lever.

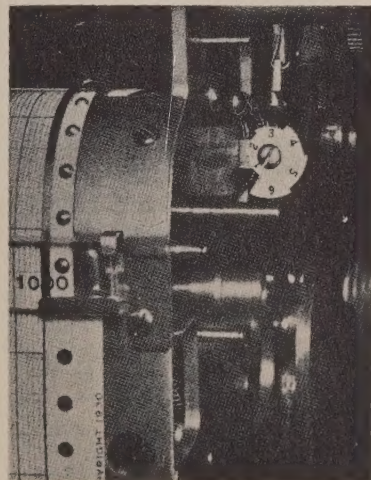
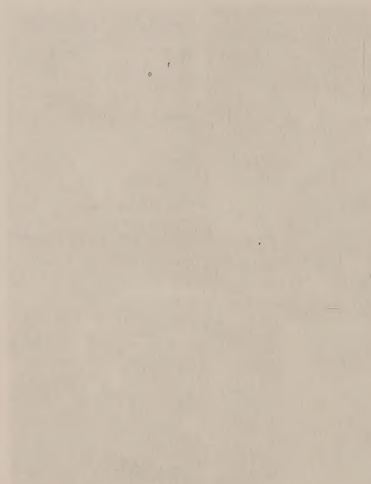


Figure 1354-3
Chart Speed Cam

This lever in its downward or forward stroke contacts the cam, moving it along to the end of its stroke. The sooner the cam is contacted, the farther it will move. The farther the cam moves, the more teeth it takes on the ratchet and the farther the chart is moved. Each tooth of the ratchet is equivalent to 1 inch of chart per hour. The speed of the chart can be varied readily by loosening the clamping screw and revolving the step cam until the desired chart speed figure falls underneath the operating lever. The numbers on the cam indicate inches of chart speed per hour. The standard chart speed is 2 inches per hour.

The American Medical Association is a non-profit corporation organized for the purpose of promoting the interests of the medical profession and the public. It is composed of members from all branches of the medical profession, and its objects are to advance the science and art of medicine, to improve the medical education of the people, and to protect the public from quackery and fraud.



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MECHANICAL OPERATION OF THE
MULTIPLE POINT PRINT HAMMER POTENTIOMETER

The mechanical operation of the Multiple Point Print Hammer Instrument can be broken up into two parts: the balancing mechanism and the recording mechanism. These are described in detail as follows:

A. BALANCING MECHANISM

The balancing mechanism is the same as that which is described in the section, "Mechanical Operation of the Single Record Potentiometer".

B. RECORDING MECHANISM

The chart drive and print carriage drive is the same as on the single record recording mechanism.

The recording mechanism has a print hammer and a multicolored ribbon instead of a pen. Different records are printed in three different colors and three different color combinations, making a total of six easily distinguishable records. A thermocouple selector switch is provided with a dial having colored sections and corresponding numbers showing which thermocouple is connected to the recorder, and which color or combination represents each couple. The entire printing and switching operation takes place during one cycle of operation of the recording mechanism, minimizing the time consumed in recording and leaving the entire record clearly exposed to view.

The time interval after a thermocouple has been connected until the recording occurs is varied by means of a selective mechanism so that the lapse of a predetermined time interval is not necessary. This results in more frequent recordings and more legible records. Without this feature, enough time should be allotted to each circuit to allow the print hammer to move to the opposite end of the scale if necessary and reach a balanced position. Obviously, this is much more time than is usually required. This selective mechanism has two sectors which are used to engage a printing tripper which actuates the print hammer and thermocouple switch.

A fine tooth sector called the "unbalanced ratchet sector" is advanced one tooth on each cycle, and a coarse-tooth sector called the "balanced ratchet sector" is permitted by a shield to advance only when the instrument is in balance. The selection of one of the two sectors is governed by a shield placed in front of the sectors. When the potentiometer is balanced, the secondary pointer will be placed opposite the long middle step of the main step lever, which stops the step lever in a definite position. A locating pin on the step lever now prevents the shield from dropping. A driving pawl is now permitted to engage the coarse-tooth sector directly, and advance it regardless of the fine tooth sector. Two movements of the coarse-tooth sector advance the tripper far enough to cause the instrument to print. The sectors are then automatically reset. When the pin on the step lever allows the pawl shield to drop, the pawl engages a tooth on the fine tooth sector. This sector has 20 teeth, which allow a maximum of 20 unbalanced strokes to occur before it advances far enough to cause the instrument to print in an unbalanced position. If, after a number of unbalanced strokes, we have one balanced stroke, the printing will not occur until the instrument has found either a second balance stroke or has accumulated a total of twenty unbalanced strokes. The reason for providing the fine tooth ratchet in addition to the coarse tooth ratchet is that it may be impossible at times for the recorder to reach a balanced position for one of the thermocouples, as for instance, when the range of the instrument is from 800 to 1800°F and the thermocouple is at a maximum temperature of 400°F. The fine tooth ratchet allows a definite maximum time to each thermocouple, after which the record is made and the next succeeding thermocouple is connected whether the galvanometer

No. of Records	SWITCH POINT NUMBER					
	1	2	3	4	5	6
2	Green	Red				
3	Green	Red	Purple			
4	Green	Red	Purple	Red and Purple		
6	Green	Red	Purple	Red and Purple	Green and Purple	Green and Red

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1355

Page No. 2

reaches a balanced position or not. By the use of the small adjustable numbered cam (shown in Fig. 1355-1), the maximum printing cycle of the instrument can be set from six up to twenty strokes. The advantage of this feature on a multi-point controller where the controlled temperatures are reasonably close together is obvious, as only a few strokes are required to reach the balanced position and pass over to the next point. This is valuable where time is an important factor in obtaining close control.

in direct proportion to the speed of the chart roll; that is, the ribbon will run out about one day after the entire chart has run through. The ribbon should be renewed at the same time the chart is renewed.

The supply ribbon reel has been provided with a friction spring which applies the proper friction to prevent the ribbon from curling. It is very important that the ribbon be renewed after having been run through once. Rollers

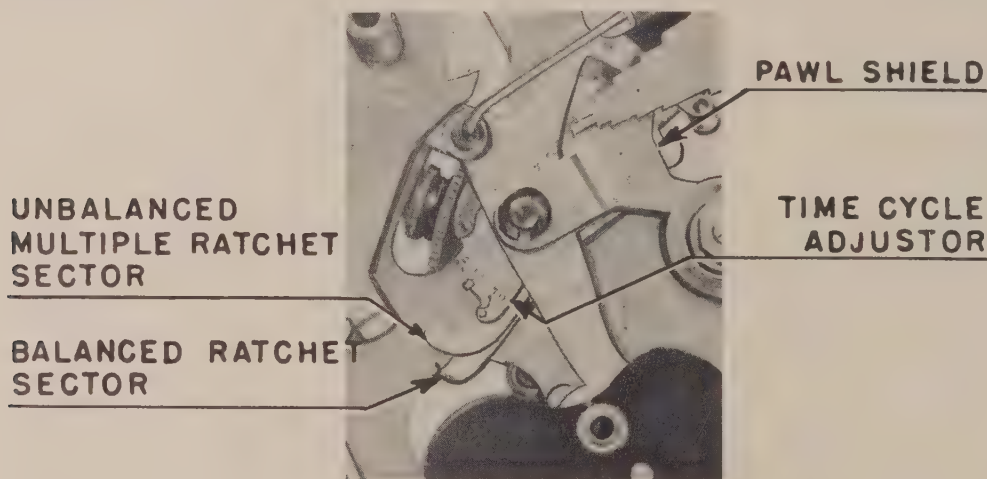


Fig. 1355-1 - Pawl Shield and Multiple Table Cam Lever Assembly

When the drive pawl has moved the balanced or unbalanced ratchet sectors through the predetermined number of steps, the balanced ratchet extension assembly moves the tripper so that it is positioned under the multiple table cam lever. These parts are shown in Fig. 1355-2. When the multiple table cam lever takes its next stroke, it pushes the tripper down. This causes the oil switch pawl to move the color cam ratchet wheel assembly one tooth. The ratchet is prevented from moving back by the retaining pawl, connected to the print hammer lever. The print hammer lever in rising upon, then dropping off, a tooth on the ratchet, causes the print hammer to rise then drop to make a mark on the chart, through the ribbon. This action from the print hammer lever to the print hammer is made by means of a link connection to the humidity compensator bar. The tripper assembly in its downward movement also sweeps the ratchet sectors back and resets them for a new cycle of operation.

The multi-colored ribbon reroll is driven by a gear on the chart drum. The ribbon is rerolled

have been provided on the ribbon carriers so that a greater tension may be applied on the spring on the left-hand ribbon stud, without increasing the pull on the driving stud. If this spring exerts too great a tension, the ribbon will tighten up, causing the ribbon carriers to pull together, which will prevent a free motion of the carrier when it drops down to position a definite color under the print hammer. The gear which drives the ribbon reroll from the left-hand side of the chart drum is fastened onto the reroll stud with a left-hand screw thread.

Before the instrument is ready to print, the printing selector lever locks the ribbon carriage so that the ribbon uncovers the last mark made on the chart. When the printing cycle has been completed, the multiple tripper contacts the printing selector lever which unlocks the ribbon carrier. The ribbon carrier falls by gravity until the pin on the right-hand side contacts the printing color selector cam. This cam has three different heights, which allows

three different stopping places for the ribbon carrier, each of which places a different color of the three-color ribbon under the print hammer. The ratchet wheel and printing color selector cam revolves one-half turn as the oil switch goes through one complete cycle. This allows for the combinations of colors which are obtained.

The print hammer, which makes a single dot on the chart, can be fitted with a stylus which produces a dot inside of a circle. The large circle-dot record is easier to read from a distance. If the print hammer does not strike the ribbon properly, it can be bent to do so.

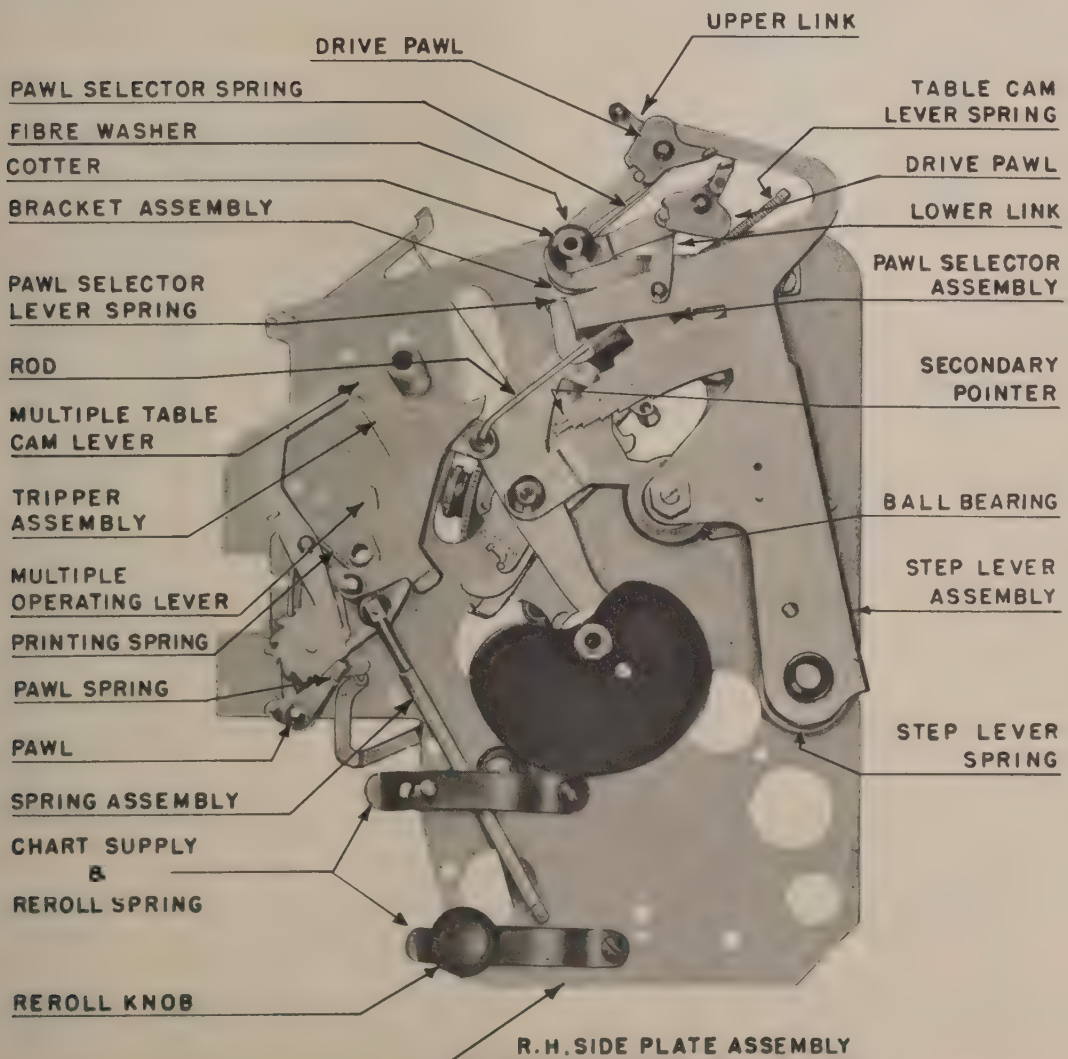


Fig. 1355-2 - Right-Hand Side Plate Mechanism of Multiple Record Print Hammer Instrument Large Gear and Ribbon Reel Removed

MECHANICAL OPERATION OF THE MULTIPLE POINT PRINT WHEEL POTENTIOMETER

The mechanical operation of the Print Wheel Instrument can be broken up into two parts: the balancing mechanism and the recording mechanism. These are described in detail as follows:

A. BALANCING MECHANISM

The balancing mechanism is the same as that which is described in the section, "Mechanical Operation of the Single Record Potentiometer".

B. RECORDING MECHANISM

The chart drive and print carriage drive is the same as on the single record recording mechanism.

The multiple record potentiometer with numeral print wheel produces records printed in colored numbers as follows:

The print wheel rotates in a plane parallel with the temperature divisions on the chart. Any inaccuracy in the indexing (which is not likely) cannot affect the accuracy of the temperature record; it will merely introduce a slight error in the time record of the character being printed.

The numeral print wheel is illustrated in Fig. 1356-1. The recording mechanism is operated by a ratchet and gear, driven from the table cam lever through the ratchet operating link assembly. The printing cam has one position at which printing occurs and the Geneva gear is rotated by drive pins on the cam. The motion of the Geneva gear is transmitted to the left-hand side-plate assembly (shown in Fig. 1356-2). A gear on this shaft drives the thermocouple switch and the large idler gear which in turn drives the spline shaft.

No. of Records	SWITCH POINT NUMBER											
	1	2	3	4	5	6	7	8	9	10	11	12
2	Green	Red										
3	Green	Red	Purple									
4	Green	Red	Purple	Blue								
6	Green	Red	Purple	Blue	Black	Brown						
8	Green	Red	Purple	Blue	Black	Brown	Green	Red				
12	Green	Red	Purple	Blue	Black	Brown	Green	Red	Purple	Blue	Black	Brown

NOTE: 16 RECORD INSTRUMENTS CAN NOT BE FURNISHED TO PRODUCE MULTI-COLOR RECORDS

The records are produced in the form of a cross with a number alongside it, thus +4. The horizontal line of the cross represents the time co-ordinate, while the vertical line represents, the temperature co-ordinate. The intersection of the two represents a point on the time-temperature curve.

The splined shaft drives the numeral print wheel and the ink pad wheel through spur gears in the print carriage assembly.

The print wheel carriage which is moved across the chart on the splined shaft by means of a spiral drive shaft, is carried entirely by the

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1356

Page No. 2

splined shaft. There is a floating drive connection between the two shafts so that binding and friction cannot occur even if the two shafts are not parallel.

Backlash between the spiral drive shaft and the print carriage mechanism is taken up by means of a coil spring operating on a plunger in contact with the shaft. Any wear occurring is taken up equally in both directions against the slope of the thread.

The impression on the chart is made when the cam lever and guide bar assembly (Fig. 1356-2) drops

in the depression of the printing cam, moving the print wheel by means of the guide bar. The correct printing pressure is applied by the printing spring.

The chart drum is made up of a metal tube with vulcanized rubber coating, similar to that used on typewriters, insuring accurate clear-cut printing, and silent operation.

Potentiometers having print wheels are supplied

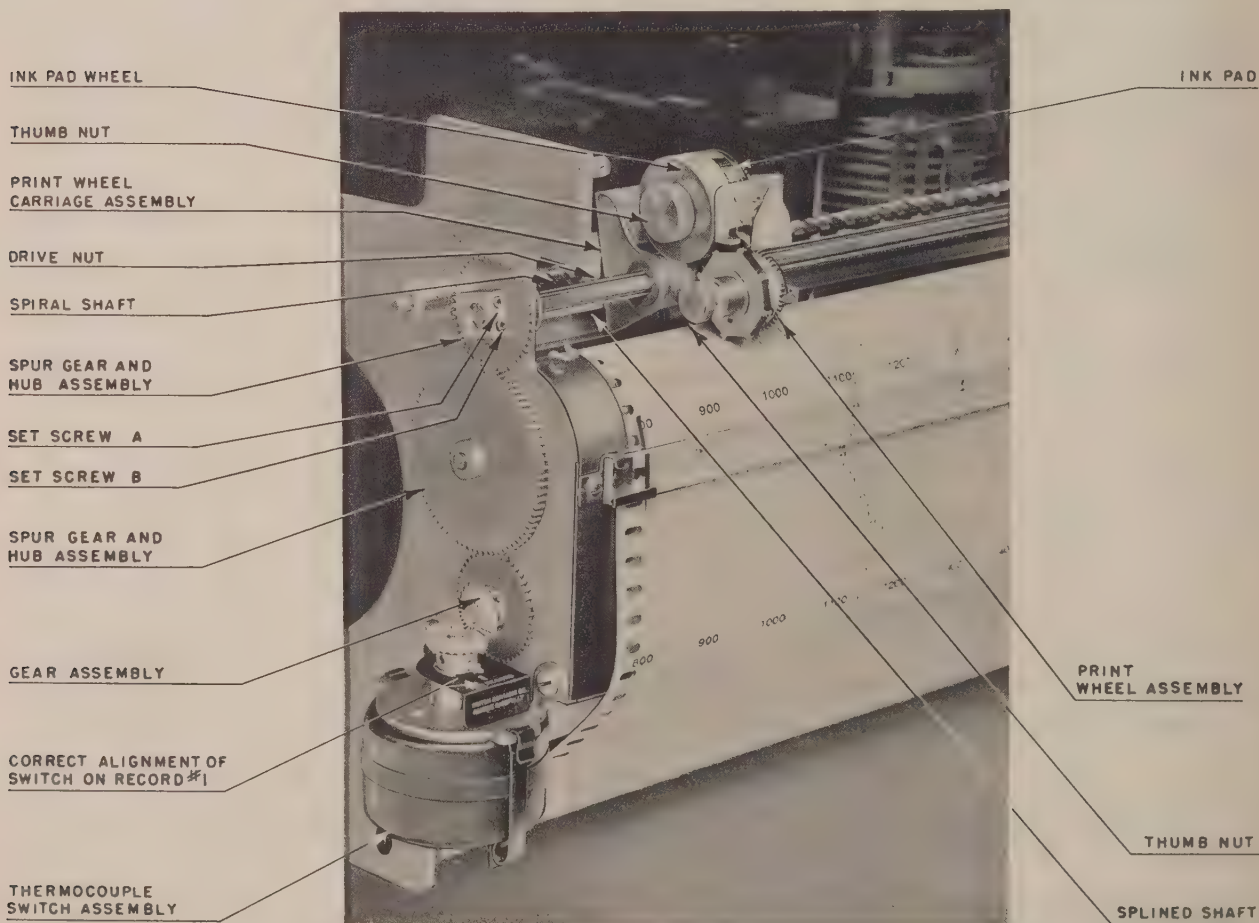


Figure 1356-1
Left-Hand Side Plate of Print Wheel Instrument
Showing Selector Switch and Printing Mechanism

in 3 styles: 1st, those printing numbers, representing the thermocouple, in one color ink; 2nd, those printing numbers in different colors of ink; and 3rd, those printing dots (no numbers) in different colors of ink.

Because the purple ink pad has a much longer life than any other color, it is used on instruments printing all records in a single color. This is felt to be a distinct advantage from the maintenance standpoint. As the purple ink pad wheel is interchangeable with the multi-color

ink pad wheel, it is possible to change from one to the other in the field, if desired.

An arrow is provided on the right-hand chart clip to be used as a guide in setting the chart to the correct time.

The humidity compensator is not supplied because of space limitations. The chart has the elongated slots on the left-hand side, so that the effect of expansion and contraction of the chart through the normal operating range, is negligible.

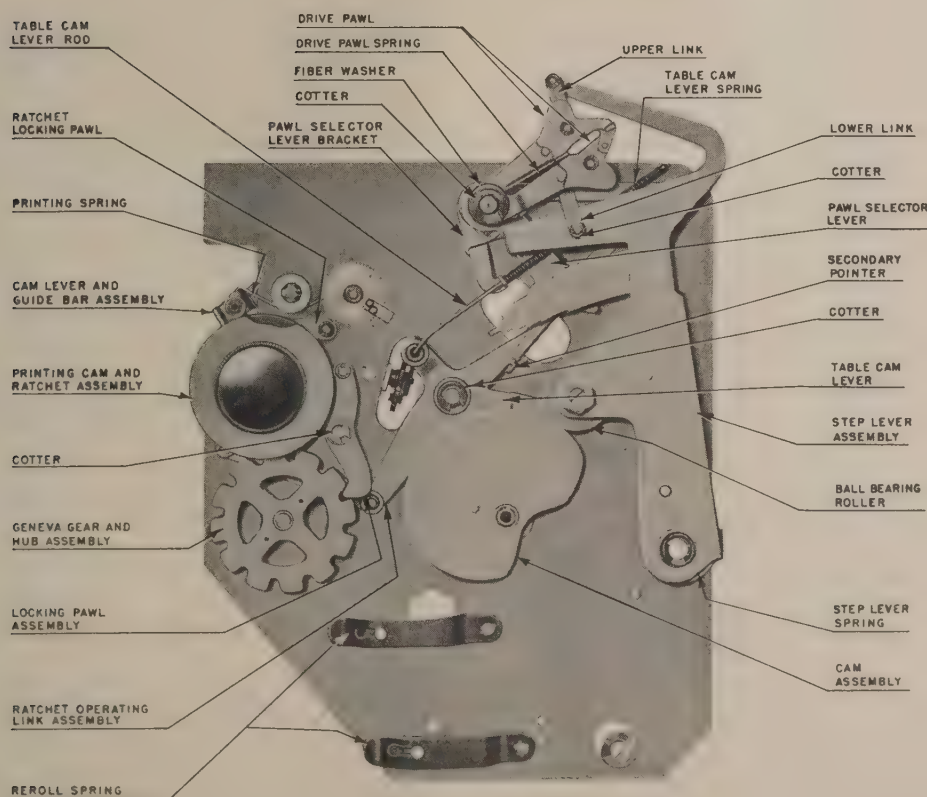


Figure 1356-2
Right-Hand Side Plate Mechanism Numeral
Print Wheel Instrument Spur Gear Removed

PRINCIPLES OF OPERATION OF THE
CONTROL MECHANISMS

The most common of the control mechanisms used with the mechanical potentiometer are covered and are listed below:

- A. Mercury Switch
- B. Proportioning Control Mechanism
- C. Program Control System
- D. Air-0-Line Controller
- E. Full Throttle Controller
- F. Beck Mechanism
- G. ATC Mechanisms
- H. Auxiliary Switch Mechanism
- I. Interrupter Switch

A. MERCURY SWITCH CONTROL MECHANISM

The mercury switch control mechanism for the Single Record and Multiple Record Instruments are described separately.

The mercury switch is a hermetically sealed glass enclosure, usually cylindrical in shape, containing a quantity of mercury, and atmosphere of hydrogen gas or a vacuum, and either two or more electrodes, or provisions for dividing the mercury into separate pools. Due to its liquid nature and electrical conductivity, the mercury will make or break an electric circuit when the switch is tilted from the horizontal position. The mercury switches are used to operate relays controlling valve action or heater loads. If the load is small enough to be handled by the mercury switch, relays are eliminated, which reduces the amount of wiring and the danger of trouble from extra contacts, and eliminates all danger of corrosion at the contacts as well as danger of explosions in the presence of explosive vapors, fumes, etc. The mercury switches can be used to operate signal lights if desired, instead of a valve.

1. Single Record Mercury Switch Control

The application of an automatic control device to a process is usually a problem of controlling the supply of a medium in response to some measured change of conditions in the process itself. The control instrument then changes the position of the control device, a valve for example, when the demand of the process itself requires such a change, which is indicated by the position of the pen with respect to the control index. The selection of the proper type of control should be based primarily upon what operating characteristics appear most desirable for the specific application.

Automatic operation of valves, relays, or power switching is accomplished through mercury switches located in the lower part of the back of the instrument. From one to three switches may be provided, depending on the type of control device to be operated.

The switches are operated by power delivered directly from the motor through the table cam. The selection of the proper switch is done by the control mechanism. On each revolution of the table cam, the control cam lever and control arm move the switch finger carrier to the left or rear of the instrument. The control lever link raises the switch finger carrier into position so that the proper switch finger contacts the proper switch arm and tips a switch in order to make or break a circuit (see Fig. 1357-1). A control knob on the outside left-hand side of the case connects through a shaft and gears to another spiral shaft, similar to the spiral pen shaft, which drives the control carriage. To set the control, it is necessary only to push in and turn the knurled knob above the door knob. Care should be taken that the knob is turned only when the control bar and table are in the UP position. The control setting may be locked by removing the control setter knob. This can be done by loosening the small screw on the control setter shaft bushing, inside the door.

The control carriage has a control step table mounted on its underside which positions a control bar, mounted parallel to and behind the scale. The number of steps on the control table determines whether the type of control is on-off, 2-position, or 3-position, which determines whether 1, 2, or 3 mercury switches are required, respectively. The control bar connects to and operates the control lever link, which positions the switch finger carrier on which the proper switch fingers are placed.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357

Page No. 2

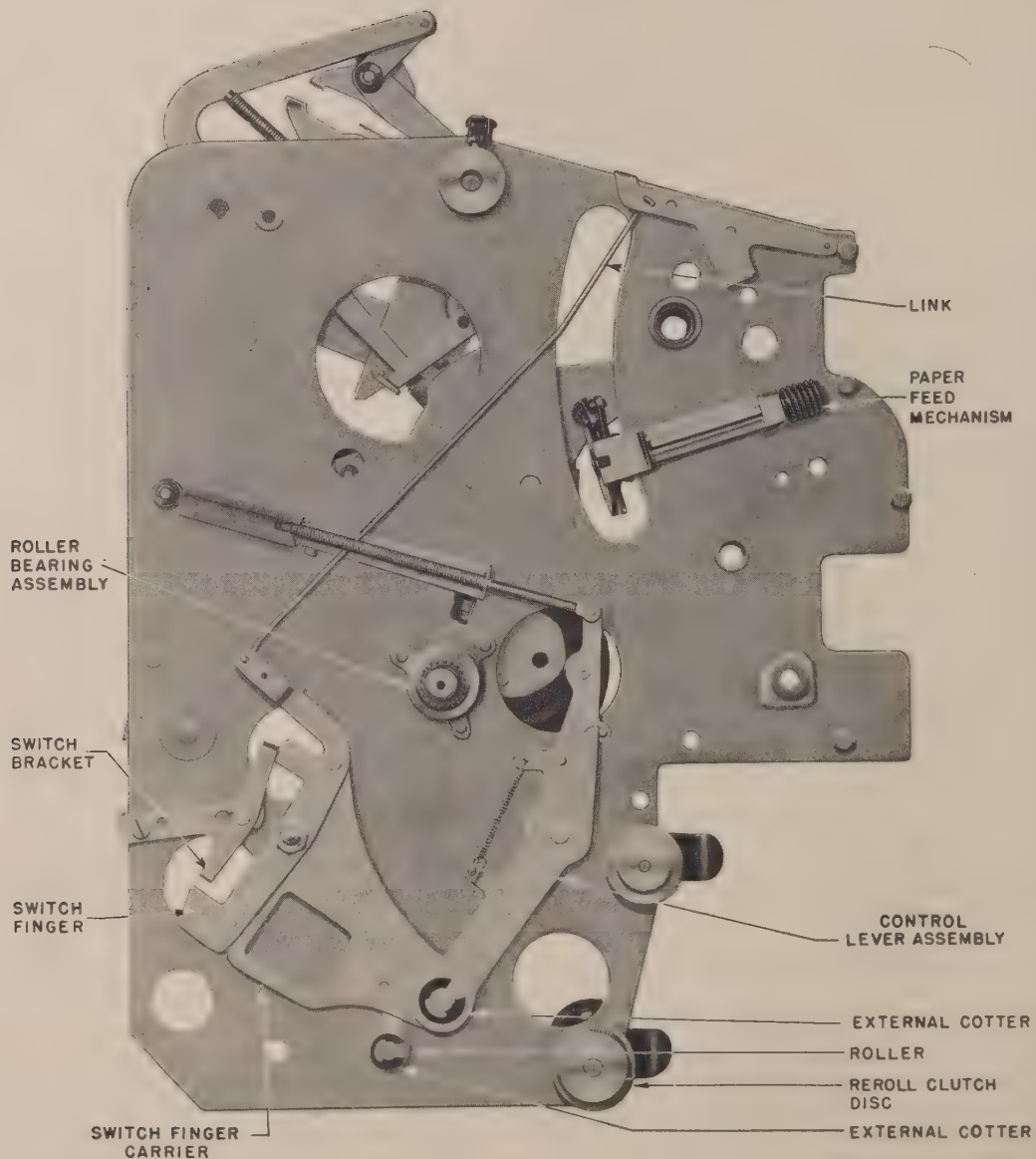
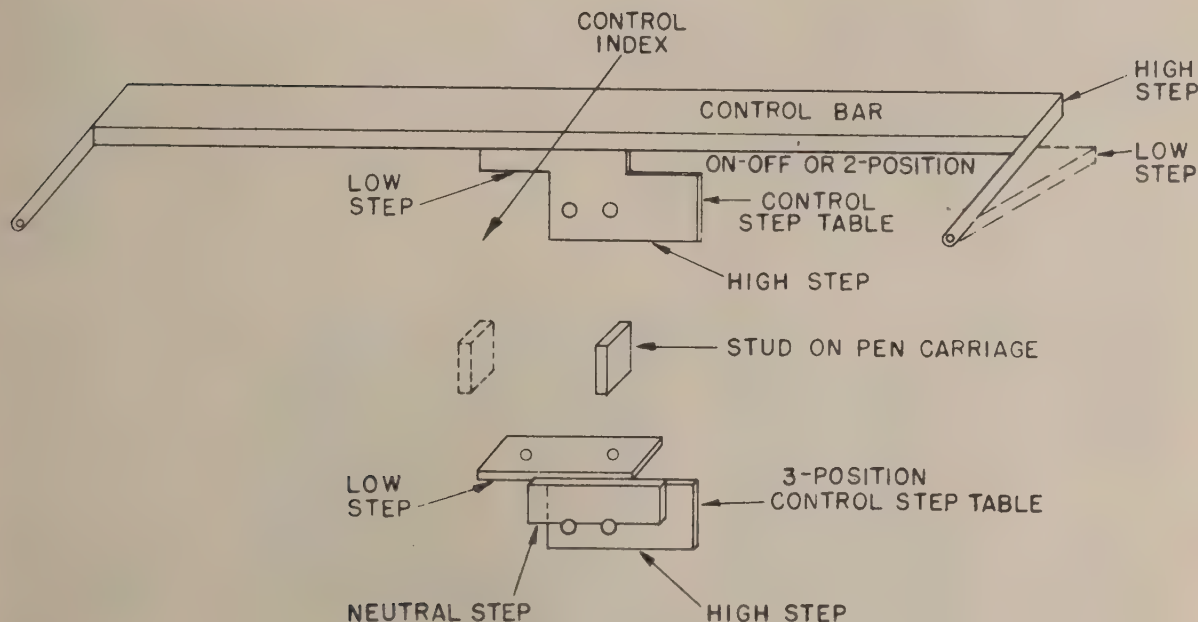


Figure 1357-1
Single Type Switch Control Mechanism
View of Inside of Right-Hand Side Plate



Drawing 16-G-07

Schematic Drawing Showing Control Step Tables and Control Bar Positions

a. On-Off Control

The on-off type of control uses one single-pole single-throw mercury switch. When the pen is below the control point, the current is turned on through the mercury switch. This energizes the motor on the control valve so that the valve opens to a definite adjustable stop. The valve stays open until the pen comes up to the control index, whereupon the switch is tipped so that the circuit through it is broken and the valve is closed by spring action.

On an electric furnace load, the circuit to the furnace or to a relay is made when the pen is below the control point and broken when the pen gets to the control point.

b. 2-Position Control

The 2-position type of control uses two single-pole single-throw mercury switches and differs from the on-off type in that, when the pen reaches the control temperature, the first switch tips off and the second switch tips on and the circuit is made through the second switch. This type of control is used on a motor valve requiring power rather than a spring to close the valve. Both on-off and 2-position control regulate the fuel supply so that it is either full-on or full-off.

The principal limitation of these two types of control mechanisms, on many applications, is the sudden change in quantity of the controlled medium. This action would be particularly undesirable in some furnace controls where a large movement of the valve would produce an appreciable change in the flame. In order to reduce the surges and to avoid large swings in the temperature, particularly on those applications where the time lag is appreciable, the movement of the valve can be reduced by adjusting the limit switches so that a movement of the valve mechanism from one limit position to another will cause only a small change in the flow of fuel to the burners.

This reduction in the amount of valve movement tends to reduce the surges and the resulting temperature control record will show a saw-tooth line of fairly small amplitude. Such an arrangement might be satisfactory under conditions where the fuel pressure and the demand on the furnace are quite steady, but a change of pressure in the fuel line or a change in the furnace load will probably require a readjustment of the valve limit positions corresponding to the two positions of the operating mechanism. For example, the mechanical connection between the motor mechanism and the valve might be changed so that the valve would operate between one-

half and two-thirds open instead of between one-third and one-half open. The control mechanism necessarily requires a valve adjustment which allows less than the required amount of controlled medium to flow when in a closed position and allows an excess to flow when the valve is in an open position. It follows, therefore, that the valve mechanism can never remain at rest for any length of time. It can never stop in the correct position but must periodically move back and forth. This inherent limitation suggests a modification; to add a third position which would be substantially what is necessary to provide a correct flow of the controlled medium at the desired operating temperature. This modification requires the control instrument to have three control contacts in place of the usual high and low contact.

c. 3-Position Control

The 3-position type of control uses three single-pole single-throw mercury switches and these switches are operated mechanically so that one of the three is tipped and a circuit made through it, depending on whether the pen is below, at, or above the control index. The operating range of the control valve itself is increased by virtue of this middle or neutral position. The valve movement from the middle to the low position or from the middle to the high position can be the equivalent of the full stroke of an on-off or a 2-position mechanism with the result that the total range of valve movement has been doubled.

d. Mechanical Operation

The control table on the control carriage limits the depression of the control bar. The control table has a step, or steps, which contact a stud on the pen carriage. This limits the downward motion of the control table and consequently the control bar. At every cycle, the control bar is lifted to its highest position and descends as low as the stud on the pen carriage will allow it. As the pen carriage approaches, reaches, and passes the control point, the stud on the pen carriage contacts first the low step, then the neutral step, and next the high step of the control table. Therefore, the step in the control table governs the position of the control bar and control arm to two or three definite stopping places, depending upon the type of control. Any change in temperature indicated by a movement of the pen carriage is transmitted by means of the con-

trol bar and control link to the switch finger carrier. The position of the control bar governs the position of the switch finger carrier. The switch finger carrier is designed so that at each of its positions, different levers of the switch assembly are moved. The movement of the switch finger carrier, which moves the mercury switches, is obtained when the control lever assembly, rolling on a positioning roller located on the lower inside part of the side plate, is driven by the table cam on the main drive shaft.

2. Multiple Record Mercury Switch Controller

In a multiple record controller, the switch selections are controlled by means of a switch finger selector lever, Fig. 1357-2, so that only one switch will be operated from a specific thermocouple. The switch finger selector lever contacts with the color selector cam (which selects the color that the instrument prints) and this contact determines the selection of the proper switch for a particular record. The position which is selected by the selector lever holds one or two switch fingers in a high, inoperative position, and allows one to drop into an operative position. The entire switch finger carrier assembly is then raised or lowered to cause the proper switch action which has been determined by the control table. Except for the switch finger selector lever, the action is similar to the single record controller.

Multiple record controllers are designed to control 1, 2, or 3 records at the same temperature, or two records at different temperatures. In the first case, the type of control applied to all records can be either on-off, 2-position, or 3-position.

In the second case, the type of control applied to both records can be either on-off or 2-position, never 3-position. With an instrument of this type, two control carriages are used, the right-hand carriage being positioned by the control setting knob above the door knob. The left-hand carriage is connected through a link with the right-hand carriage. The link has a slot and the left-hand carriage can be set to any distance within the length of the slot away from the right-hand carriage, by pushing or pulling the left-hand carriage with the right-hand carriage.

Either control carriage can be fastened at any position on the scale by tightening the tail thumb screw (one for each carriage) showing above the scale.

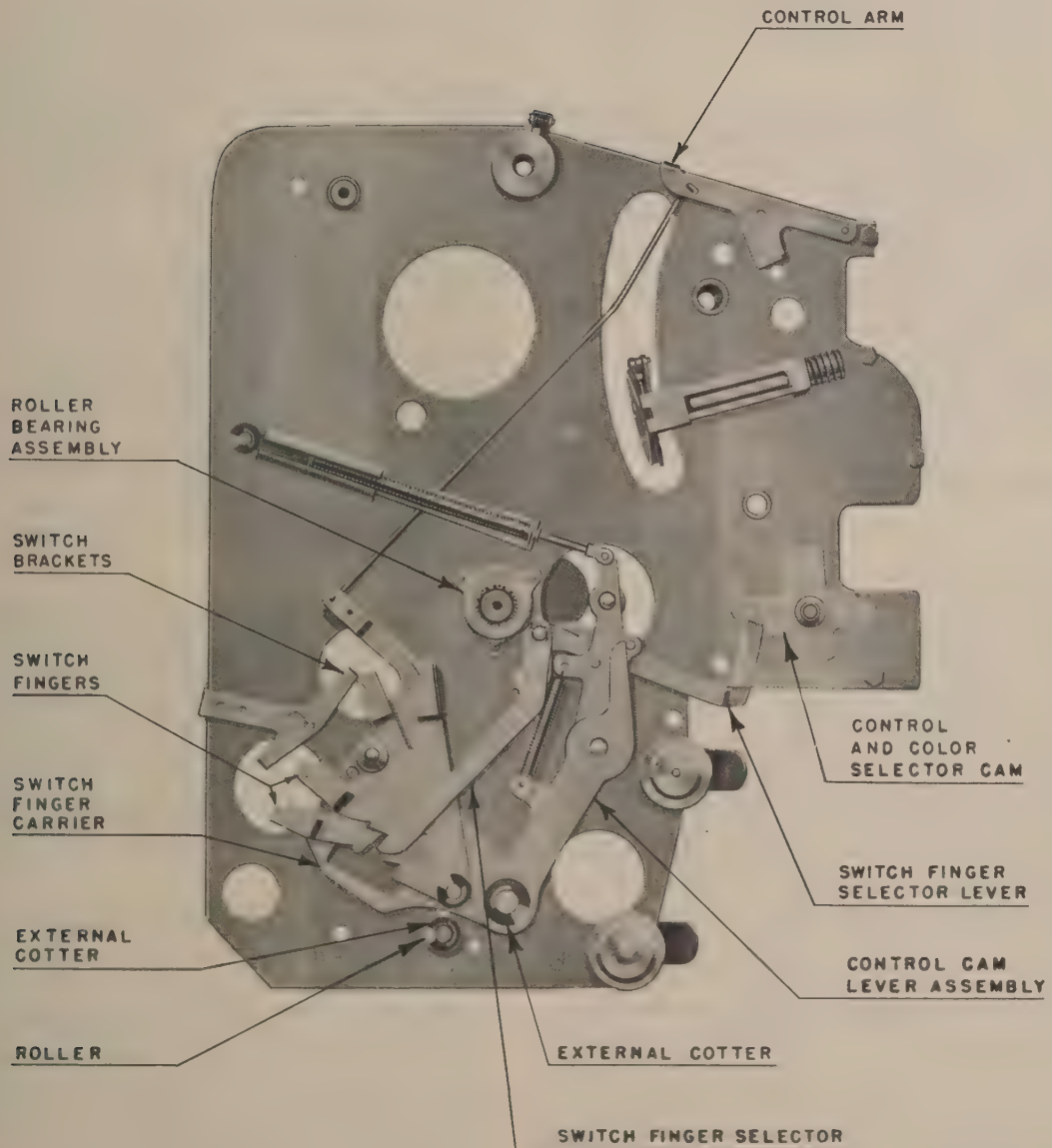


Figure 1357-2
Multiple Type Switch Control Mechanism
View of Inside of Right-Hand Side Plate

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357

Page No. 6

The three steps available for 3-position control at the same temperature point are split up so that the low and neutral step apply to the lower control temperature point, while the neutral and high step apply to the higher temperature control point. The same neutral step is used as high for one temperature and low for the other. This selection is accomplished by the switch finger selector lever.

Multiple controlling instruments are supplied in various combinations. An instrument may record on one or more points and control on one record only. These controllers have special mechanisms to hold the switch fingers inoperative while the instrument is recording on the temperatures which are not being controlled. All instruments of this type are furnished with special instructions.

The maximum control setting on single or multiple record control instruments using mercury switches is $3/4$ " below the full scale pen position. This is a constructional limit.

B. SINGLE RECORD PROPORTIONING CONTROL

A further development is the "proportioning system" of control, which uses an electro-mechanical method for securing modulation of motion of the valve by utilizing a standard alternating current supply circuit. This system provides a number of steps between full-open and full-closed valve position. The high-low control temperature limits are spanned by a wire wound resistance of 135 ohms, the extremities of which are connected to two wires of the control circuit. A sliding contact, which takes its position from the relation of the pen with respect to the control temperature, is connected to the third wire, hence dividing the resistance into two arms. As this contact is moved over the resistance, it varies the ratio of the two arms of the electrical transmission system, essentially a Wheatstone Bridge. Hence, there is no waiting for the making of a high, low, or neutral or some other definite control circuit before a reaction occurs at the motor driven device.

To describe the operation, first assume that the pen is at the control index and the sliding contacts in all the units shown are in a balanced position as shown in Dwg. 16-G-08, which is a diagrammatic presentation of the circuits of the proportioning system that incorporates the three separate elements, namely, the control instrument or potentiometer, the transformer, and the power or motor unit which houses the balancing relay.

Under these conditions, the resistances HC, CL, BR and RW are balanced and the current flowing in coil C_1 is equivalent to that flowing in coil C_2 . The armature will then be acted upon by equal magnetic forces from coils C_1 and C_2 and the blade will be held in the center of the gap between the two relay contacts. The motor will be at rest when the relay armature is in this center position.

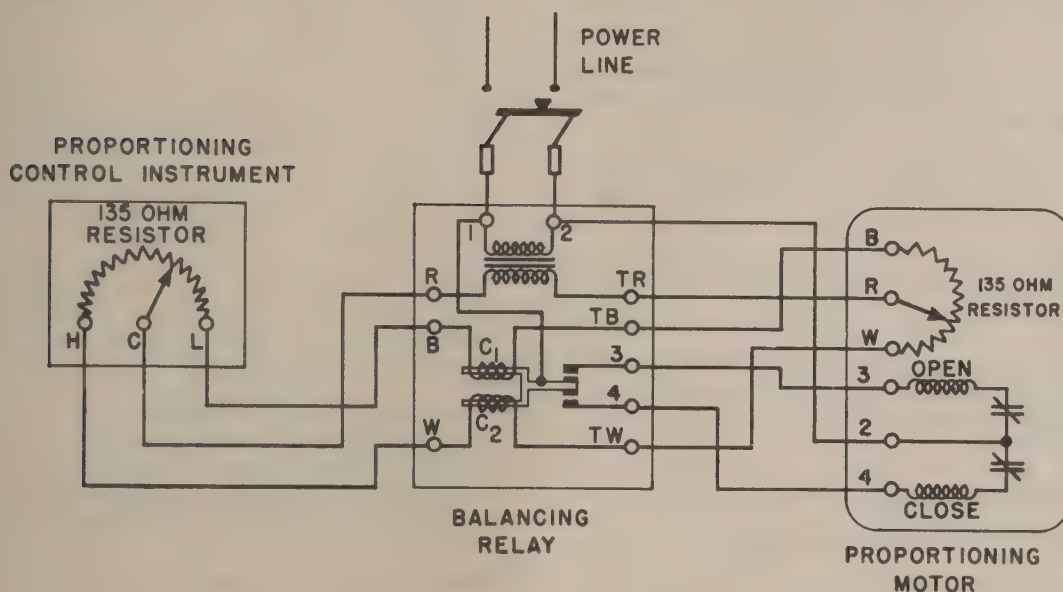
Any deflection of the pen away from the control index will unbalance the bridge. Assuming that this moves the contact C toward the extremity H there will be an immediate unbalance in the electrical system as the resistance $HC + RW$ will be less than $CL + BR$. The net result is that more current will flow in the circuit of coil C_2 than in that of C_1 . The armature will then move toward coil C_2 due to the increased magnetic effect and the blade will make with contact #4.

With this circuit closed the motor will tend to close the control valve and at the same time the sliding contact R on the resistor in the proportioning motor will move toward B until the bridge circuit is rebalanced. When this rebalance occurs, equal currents flow through the coils C_1 and C_2 and the relay blade returns to the center of the gap between contacts 3 and 4, stopping the proportioning motor.

It is evident that when the relay is in its central position, the motor unit in bringing it to that balance has rotated an amount which is proportional to the deflection of the primary controlling device. From this particular feature is derived the name "proportioning control", defined as an equality of ratios. A very important feature in the operation of this system is that the reversing motor elements within the power unit operate only when a change of position is demanded by the controller.

The slope of the control table on the control carriage is designed to give full-open to full-closed valve position for a pen movement of 2.4 to 6% of the full scale pen movement (called throttling range) in four adjustable steps of 2.4, 3.6, 4.8, and 6.0%. A throttling range of 4 to 10% having steps of 4, 6, 8, and 10%, or a range of 1.1 to 2.0% with steps of 1.1, 1.4, 1.7, and 2.0% can be supplied. The maximum control setting for the proportioning controller is $1-1/2$ " below the full scale pen position.

A feature of the proportioning control which has not been covered is the number of resistors which can be used with a single pen. There is enough space in the mercury switch compartment to insert four resistors. Each of these resistors is connected to its own valve mechanism.



Drawing 16-G-08
Schematic Wiring Diagram
Proportioning Control Systems

Accordingly, one thermocouple can control the position of one to four proportioning motor-operated valves. The arrangement for two temperatures is similar, and one, two, or three resistors can be operated from one thermocouple while the remaining resistor or resistors are operated from another thermocouple. When positioning the contacts on the resistors, they can be offset so that all the valves do not open to the same point for a definite pen position in relation to the control point.

1. Multiple Record Proportioning Control

Proportioning controllers are supplied for multiple record instruments. The number of recorded points is limited to 5. One or two records can be controlled at the same or at different temperatures. When one record in five is to be controlled, a six-segment oil switch is used, on which the fifth segment records the control temperature and the control is operated when the sixth segment is moved in contact after the fifth point has balanced. For controlling one record in four, a six-segment switch is also used. The instrument records points 1, 2, 3, and 4, which is the controlled record. No. 5 and No. 6 segments are connected to control the No. 4 record. To control one record in three, a four-segment

switch is used in which the fourth segment controls the No. 3 record after No. 3 has balanced and printed. In all the above cases, a mercury switch is placed on the left-hand side plate of the instrument to break the power circuit to the relay so that the control circuit will function only when the control segment is in contact. When two records are controlled at two different temperatures, the instrument has two control tables, two control bars, and two control contacts on two different resistors. There is also a mercury switch, single-pole double-throw, mounted on the left-hand side plate, to break the electrical control circuit except when the control segment for the controlled record is connected.

C. THE PROGRAM CONTROL SYSTEM

The Brown Program Control System consists essentially of a Potentiometer Pyrometer on which is installed a means of moving the control index up and down scale at a predetermined rate. Moving this index at a certain time rate and in a desired direction produces a cycle of heating or cooling which is called a program.

The program control system provides the following functions in addition to the usual control features:

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357

Page No. 8

1. A predetermined heating rate from one point to another predetermined point on scale or chart.
2. A holding or "soaking" period of predetermined length during which the control index remains stationary.
3. A predetermined cooling rate from one predetermined point to another point on the scale or chart.

Depending upon the individual design of the circuit the above functions may be combined in an almost infinite number of ways.

For a reference to the particular application, refer to the wiring diagram which accompanies the shipment. This diagram includes the following information.

1. Actual connection between all equipment
2. Graph of the desired program
3. Schematic wiring diagram
4. Sketch of the operation of the circuit

Various auxiliary equipment is used to accomplish the control actions of the program control system. A rate controller is used in series with the windings of the control point drive motor in order to adjust the rate of downscale or upscale drive.

A soaking time controller is used to time the length of the holding or "soaking" periods and is sometimes used to time the rate of upscale or downscale drive.

All throughout the program the temperature is controlled through the usual control circuit of the potentiometer.

1. Description of the Program Equipment

After the installation of the Program Control System has been completed, the schematic wiring illustrated on the wiring diagram which accompanies these instructions should be carefully reviewed in order to ascertain the operation of the control system.

a. Control Point Drive Mechanism

The motor drive for control point setting consists of a small reversible synchronous motor which is used to drive an adjustable gear train. It is supplied on potentiometer

type instruments, and is mounted near the left-hand sideplate by means of two screws which are screwed into tapped holes in the instrument frame.

The connections to the motor are shown on the internal wiring diagram of the controller, which is listed on the external diagram, and furnished upon request. As its name implies, the mechanism drives the control index either upscale or downscale, depending on which winding of the motor is energized.

The Drawing 16-G-09 illustrates the $1/2''$ - $1/16''$ per minute control point drive. It is important to note that only this drive has a speed change.

All other control point drives are set for only one speed. These drives might be of the following speeds - 2.77, 1.385, .948, or .474 inches per hour. Referring to your particular order will give the speed of the particular drive.

b. Auxiliary Switch Mechanism

The auxiliary switch mechanism may be mounted on either the right-hand sideplate or left-hand sideplate of the instrument chassis. The mechanism may have either one or two single throw mercury switches. Therefore, the contact operation may be either SPST, or SPDT, or DPST.

The switch mechanism may be driven from either the control shaft or the pen shaft; in other words, operated from the position of the pen, or the position of the control index.

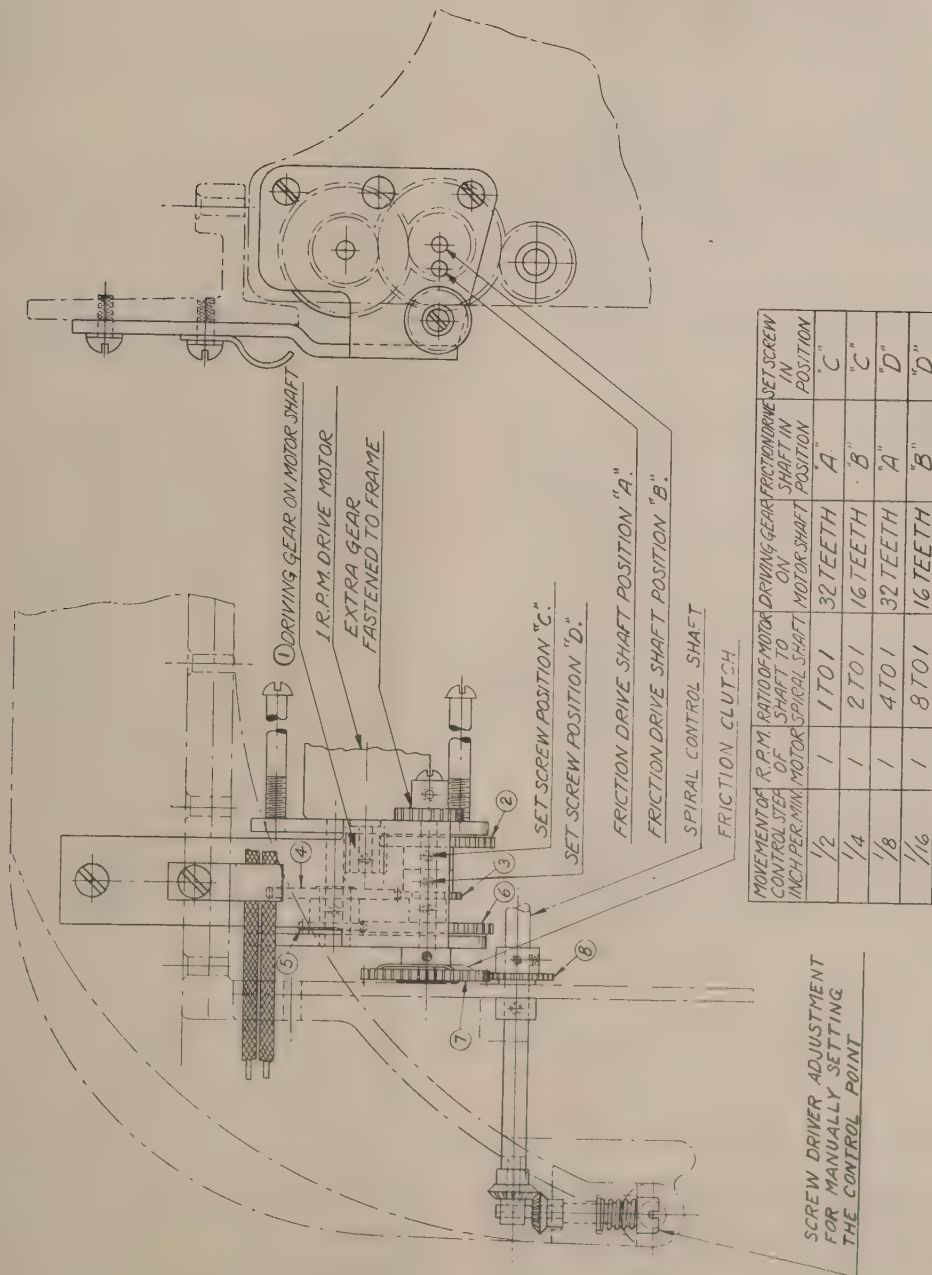
For program control systems, the auxiliary switch mechanism will usually be operated from the control index.

The switch is tilted when two slotted discs, driven by gears from the pen or control shaft, come in alignment.

c. Soaking Time Controller

Except in unusual cases, the soaking time controller used in the program control system will be an Automatic Temperature Control Company vernier set timer.

Never under any circumstances should the electrical arrangement of the soaking time controller be altered by moving the jumpers X, Y, or Z on the terminal block or by moving the red, yellow, or green slides because this will prevent the program from following the desired sequence.



MOTOR DRIVE FOR POTENTIOMETER CONTROL SETTING

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357

Page No. 10

The soaking time controller requires a contact to energize the timing mechanism. The mechanism then makes a contact during, and another contact after timing. These contacts are used to further the program sequence.

d. Rate Controller

Except in unusual cases, the rate controllers used in the program control system will be an Automatic Temperature Control Company current input controller.

In most cases the dial of the rate controller is calibrated directly in terms of temperature rise or fall per hour (degrees per hour).

The rate controller makes a contact for the percentage of time indicated on the dial. The rate controller has an adjustable contact closure of 0-100% and has a dial calibrated 0-100%. Therefore, if the dial setting is 70% the contact is made 70% of a certain period and broken for 30% of the same period.

When specified, the rate controller can be supplied with an adjustable contact closure of 0-40% and with a dial calibrated 0-100%. Therefore, if the dial is set at 70%, the contact is closed 70% times 40%, or 28% of the period.

Reference to your particular order will show whether the rate controller has an adjustable contact closure of 0-100% or 0-40%. If no specification is given on the order, the contact closure will be the standard 0-100%.

e. Auxiliary Equipment

Other equipment such as relays, push buttons, etc. do not require any adjustments.

D. THE BROWN AIR-0-LINE CONTROLLER

The Brown Air-0-Line Potentiometer Controller is the air operated instrument which contains full throttling and automatic reset mechanisms. This instrument has an adjustable throttling range from on-off operation up to 150% and a full range of automatic reset rates. The element used for measuring temperatures may be either a thermocouple or resistance thermometer bulb.

1. Principle of Operation of the Brown Air-0-Line

Dwg. 10-G-93 shows a schematic diagram of the Brown Air-0-Line Potentiometer Controller, applied to a steam heated tank. The temperature in tank (31) is measured by thermocouple (32), and controlled by the steam flow through valve (9).

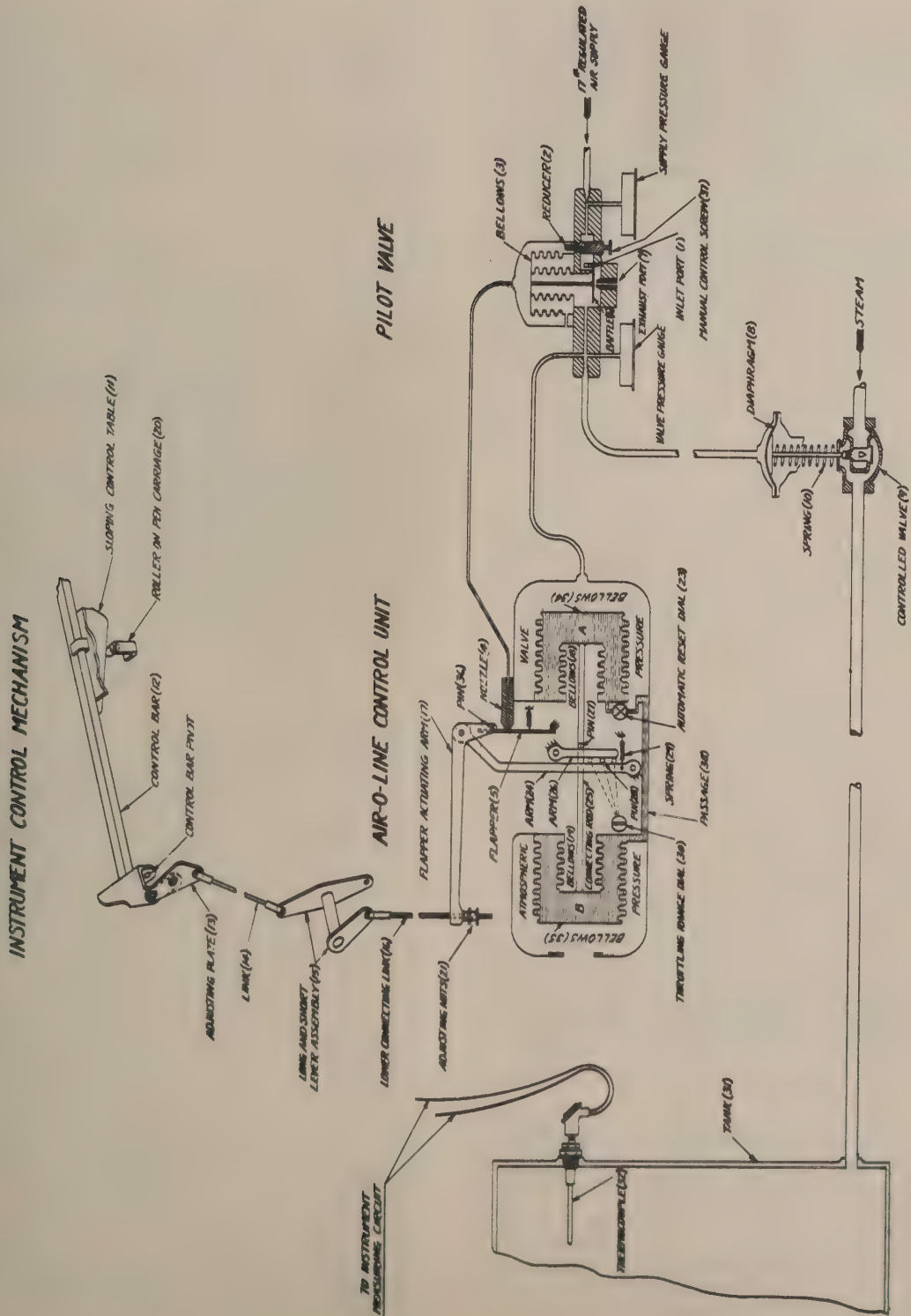
a. Pilot Valve

A schematic diagram of the pilot valve is shown on the right side of Dwg. 47-S-76-E. This pilot valve is of the multiplying type, that is, it multiplies changes in the nozzle pressure to give the resultant valve pressures. The function of the pilot valve is to utilize the comparatively low pressure in the nozzle system to operate larger ports which rapidly admit air to and from the diaphragm valve.

An external regulator applies air at 17 lbs. to inlet port (1), and through reducer (2) to bellows (3) and nozzle (4). Reducer (2) is smaller than nozzle (4) so that when flapper (5) is off nozzle (4), there is no pressure on bellows (3) which causes baffle (6) to cover inlet port (1) and to uncover exhaust port (7). This exhausts the air from controlled valve diaphragm (8) and permits spring (10) to close controlled valve (9). When flapper (5) covers nozzle (4), the air through reducer (2) increases the pressure on bellows (3) which moves baffle (6) to uncover inlet port (1) and cover exhaust port (7), increasing the pressure on controlled valve diaphragm (8) which opens controlled valve (9) against the force of spring (10).

b. Control Index Setting Mechanism

The pen carriage, equipped with a special split nut bearing, has a roller (20) which contacts a sloping control table (11). The sloping control table is fastened to the control carriage. To set the control carriage at the desired temperature, it is necessary only to push in and turn the knurled knob above the door knob. The sloping control table (11) also is fastened to the control bar (12), which is raised and lowered by the roller (20) on the pen carriage, depending on the position of the recording pen in relation to the control point. The motion of this bar (12) is transmitted by the upper connecting link (14) to the extension, toward the rear of the case of the long arm in a long and short lever assembly (15). The short arm of this long and short lever assembly, through lower connecting link (16), operates flapper actuating arm (17).



Dwg. 10-G-93 - Schematic Drawing
Potentiometer Air-O-Line Controller

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357

Page No. 12

With the recording pen at the control point, through the linkage described above, the flapper actuating arm (17), lets flapper (5) just touch nozzle (4), when arm (24) is in the vertical position shown. If the temperature rises and moves the pen upscale from the index only slightly, control bar (12) is moved upward which, through the linkage, rotates flapper actuating arm (17) clockwise. This slight motion lifts flapper (5) from nozzle (4), which operates the pilot valve and exhausts air from the controlled valve (9). The slightest downscale pen movement from the index, through the same levers, rotates flapper actuating arm (17) counter-clockwise and lets flapper (5) cover nozzle (4). This operates the pilot valve and admits air to the controlled valve (9). Likewise, if the pen were stationary, and the index setting were moved away from the pen, similar motion would be transmitted to the flapper actuating arm (17) to operate the controlled valve (9).

By simply connecting the upper connecting link (14) to the opposite extension of the long arm (15), the opposite motion is transmitted to the operating pin (36), so that by these connections to the long arm (15), the flapper actuating arm (17) may be made to either increase or decrease the pressure to the diaphragm valve (9), with decrease of temperature.

c. Air-O-Line Control Unit

The primary function of the Air-O-Line control unit is to provide a means of governing the valve pressure change resulting from a given pen movement. This unit is interposed between the action of the pen, (or other measuring element) on the flapper, and the pilot valve. Without this unit, the pen would operate the flapper and the pilot valve to produce on-off control action; i.e., any slight separation of the pen and the index would cause the controlled valve to either completely open or close. "Throttling" or "Proportioning" action is produced as follows:

d. Throttling Action

If the temperature decreases, moving the pen downscale causes the flapper actuating arm (17) to rotate counter-clockwise, which allows flapper (5) to cover nozzle (4). The air flow through reducer (2) then increases the pressure on bellows (3) which moves baffle (6) off inlet port (1) and towards exhaust port (7), increasing the controlled valve pressure, admitting more steam. The controlled

valve pressure simultaneously acts upon bellows (18). As bellows (18) is compressed, its motion through rod (25) and pin (27) is transmitted to reset arm (26) and, in turn, to pin (28) on arm (24) which carries flapper actuating arm (17) moving flapper (5) away from nozzle (4). Therefore, flapper (5) is moved away from nozzle (4) nearly the full distance the pen moves it toward nozzle (4).

The distance the bellows pushes flapper (5) back off nozzle (4) is governed by the distance flapper actuating arm (17) is moved by bellows (34) which distance, in turn, is governed by the position of pin (28). For a given downscale pen movement, there is secured a net flapper movement and a net controlled valve pressure change, dependent upon the position of pin (28). Therefore, for a given position of pin (28), there is a definite flapper position and a definite controlled valve pressure for each pen position. This proportionality between pen movement and resultant controlled valve pressure change, is known as "Throttling Range". Throttling range is expressed as the percent of full scale pen movement required to change the controlled valve pressure from 0 to 15 lbs. The position of pin (28), or the Throttling Range, is adjusted by turning throttling range dial (30).

It will be noted that the demand for more steam caused the pen to move downscale, which resulted in a wider opening of the controlled valve. This increased valve opening varies directly with the distance the pen moves below the index. The greater the demand for more steam, the farther the pen must move downscale from the index to obtain this increased steam flow. Since there is a definite controlled valve pressure for each pen position, the increased steam flow can be obtained only as long as the pen remains below the control index; a distance corresponding to the increased steam demand. If the pen is to be returned to the desired temperature, it is necessary to increase the controlled valve pressure and admit more steam than has resulted from this downscale pen movement. This requires that the flapper moves nearer the nozzle. This can be done mechanically by setting the control index upscale, which, through the linkage, rotates flapper actuating arm counter-clockwise. Of course, the control index is then no longer at the controlled temperature. A similar movement of the flapper toward the nozzle without resetting the index is accomplished automatically in the Brown Air-O-Line Unit.

e. Automatic Reset

An increase in the controlled valve pressure increases the pressure on liquid (A) between bellows (34) and (18). The liquid then flows from space (A) through the needle valve, adjusted by automatic reset dial (23) and passage (38), to space (B), causing connecting rod (25), carrying pin (27), to move to the right. Spring (29) causes arm (24) and flapper actuating arm to follow. This moves flapper (5) toward nozzle (4) increasing the controlled valve pressure. The rate at which flapper (5) is moved, and the controlled valve pressure is increased, depends upon the rate at which the liquid flows from (A) to (B), or upon the pressure difference between (A) and (B), which depends upon the distance of the pen below the control index.

The controlled valve pressure increases, admitting more steam and raising the temperatures in tank (31). As the pen moves upscale, the pressure difference between (A) and (B) decreases until they are at equal pressures, at which point the pen will coincide with the control index. There is no further increase in controlled valve pressure. The controlled valve has been opened to supply enough steam to restore the temperature to the control point.

It is important to note that after such a pen departure, if the pen returned upscale abnormally fast, the control bar (12) moves the flapper actuating arm (17) so as to lift flapper (5) faster than the reset liquid displacement moves flapper actuating arm (17) to let flapper (5) cover nozzle (4), with the result that the valve pressure is decreased as the pen approaches the control index. By the same means, if the pen moves upscale abnormally slowly, the liquid displacement from (A) to (B) causes flapper (5) to cover nozzle (4), increasing the valve pressure further. Therefore, the Air-O-Line unit, by means of its Throttling Range and Automatic Reset, recognizes the amount of departure, and the rate at which the pen moves, and makes corrections accordingly.

By similar upscale pen movement, lower valve pressures may be established to reduce steam flows sufficiently to maintain the pen at the control index.

E. THE BROWN FULL THROTTLER CONTROLLER

The Brown Full Throttler Potentiometer Controller is the air operated instrument which contains full

throttling and manual reset mechanisms. This instrument has an adjustable throttling range from on-off operation up to 150 per cent and a full range of manual reset points. The element used for measuring temperatures may be either a thermocouple or resistance thermometer bulb.

1. Principle of Operation of the Brown Full Throttler

Drawing 16-G-11 shows a schematic diagram of the Brown Full Throttler Potentiometer Controller, applied to a steam heated tank. The temperature in tank (31) is measured by thermocouple (32), and controlled by the steam flow through valve (9).

a. Pilot Valve

A schematic diagram of the pilot valve is shown on the right side of Figure 16-G-11. This pilot valve is of the multiplying type, that is, it multiplies changes in the nozzle pressure to give the resultant valve pressures. The function of the pilot valve is to utilize the comparatively low pressure in the nozzle system to operate larger ports which rapidly admit air to and from the diaphragm valve.

An external regulator applies air at 17 lbs. to inlet port (1), and through reducer (2) to bellows (3) and nozzle (4). Reducer (2) is smaller than nozzle (4) so that when flapper (5) is off nozzle (4), there is no pressure on bellows (3) which causes baffle (6) to cover inlet port (1) and to uncover exhaust port (7). This exhausts the air from controlled valve diaphragm (8) and permits spring (10) to close controlled valve (9). When flapper (5) covers nozzle (4), the air through reducer (2) increases the pressure on bellows (3) which moves baffle (6) to uncover inlet port (1) and cover exhaust port (7), increasing the pressure on controlled valve diaphragm (8) which opens controlled valve (9) against the force of spring (10).

b. Control Index Setting Mechanism

The pen carriage, equipped with a special split nut bearing, has a roller (20) which contacts a sloping control table (11). The sloping control table is fastened to the control carriage. To set the control carriage at the desired temperature, it is necessary only to push in and turn the knurled knob above the door knob. The sloping control table (11) also is fastened to the control bar (12), which is raised and lowered by the

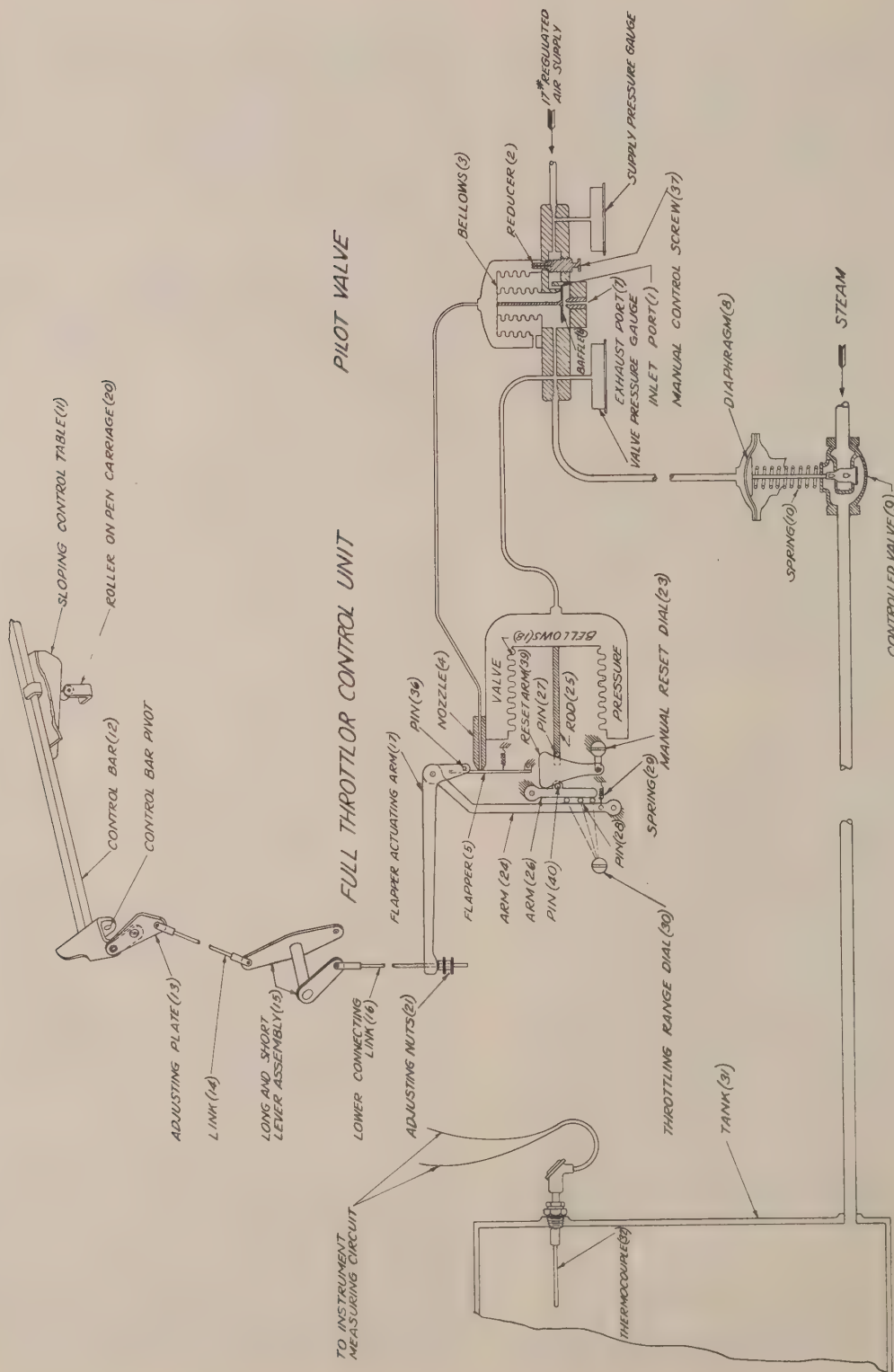


Fig. 16-G-11
POTENTIOMETER FULL THROTTLOR CONTROLLER

roller (20) on the pen carriage, depending on the position of the recording pen in relation to the control point. The motion of this bar (12) is transmitted by the upper connecting link (14) to the extension, toward the rear of the case, of the long arm in a long and short lever assembly (15). The short arm of this long and short lever assembly, through lower connecting link (16), operates flapper actuating arm (17).

With the recording pen at the control point, through the linkage described above, the flapper actuating arm (17), lets flapper (5) just touch nozzle (4), when arm (24) is in the vertical position shown. If the temperature rises and moves the pen upscale from the index only slightly, control bar (12) is moved upward which, through the linkage, rotates flapper actuating arm (17) clockwise. This slight motion lifts flapper (5) from nozzle (4), which operates the pilot valve and exhausts air from the controlled valve (9). The slightest downscale pen movement from the index, through the same levers, rotates flapper actuating arm (17) counter-clockwise and lets flapper (5) cover nozzle (4). This operates the pilot valve and admits air to the controlled valve (9). Likewise, if the pen were stationary, and the index setting were moved away from the pen, similar motion would be transmitted to the flapper actuating arm (17) to operate the controlled valve (9).

By simply connecting the upper connecting link (14) to the opposite extension of the long arm (15), the opposite motion is transmitted to the operating pin (36), so that by these connections to the long arm (15), the flapper actuating arm (17) may be made to either increase or decrease the pressure to the diaphragm valve (9), with decrease of temperature.

c. Full Throttler Control Unit

The primary function of the Full Throttler Control Unit is to provide a means of governing the valve pressure change resulting from a given pen movement. This unit is interposed between the action of the pen, (or other measuring element) on the flapper, and the pilot valve. Without this unit, the pen would operate the flapper and the pilot valve to produce on-off control action; i.e., any slight separation of the pen and the index would cause the controlled valve to either completely open or close. "Throttling" or "Proportioning" action is produced as follows:

d. Throttling Action

If the temperature decreases, moving the pen downscale causing the flapper actuating arm (17) to rotate counter-clockwise, which allows flapper (5) to cover nozzle (4) the air flow through reducer (2) then increases the pressure on bellows (3) which moves baffle (6) off inlet port (1) and towards exhaust port (7), increasing the controlled valve pressure, admitting more steam. The controlled valve pressure simultaneously acts upon bellows (18). As bellows (18) is compressed, its motion through rod (25) and pin (27) is transmitted to reset arm (39) and, in turn, to pin (40) on arm (26) and through pin (28) to arm (24), which carries flapper actuating arm (17) moving flapper (5) away from nozzle (4). Therefore, flapper (5) is moved away from nozzle (4) nearly the full distance the pen moves it toward nozzle (4).

The distance the bellows pushes flapper (5) back off nozzle (4) is governed by the distance flapper actuating arm (17) is moved by bellows (18) which distance, in turn, is governed by the position of pin (28). For a given downscale pen movement, there is secured a net flapper movement and a net controlled valve pressure change, dependent upon the position of pin (28). Therefore, for a given position of pin (28), there is a definite flapper position and a definite controlled valve pressure for each pen position. This proportionality between pen movement and resultant controlled valve pressure change, is known as "Throttling Range". Throttling range is expressed as the percent of full scale pen movement required to change the controlled valve pressure from 0 to 15 lbs. The position of pin (28), or the Throttling Range, is adjusted by turning throttling range dial (30).

It will be noted that the demand for more steam caused the pen to move downscale, which resulted in a wider opening of the controlled valve. This increased valve opening varies directly with the distance the pen moves below the index. The greater the demand for more steam, the farther the pen must move downscale from the index to obtain this increased steam flow. Since there is a definite controlled valve pressure for each pen position, the increased steam flow can be obtained only as long as the pen remains below the control index; a distance corresponding to the increased steam demand. If the pen is to be returned to the desired temperature, it is necessary to increase the controlled

valve pressure and admit more steam than has resulted from this downscale pen movement. This requires that the flapper moves nearer the nozzle. This can be done mechanically by setting the control index upscale, which, through the linkage, rotates flapper actuating arm counter-clockwise. Of course, the control index is then no longer at the controlled temperature. A similar movement of the flapper toward the nozzle without resetting the index is accomplished manually in the Brown Full Throttlor Unit.

e. Manual Reset

Reset arm (39) has variable width. Turning manual reset screw (23), clockwise, raises arm (39). As the width of arm (39) decreases, spring (29) pulls arm (24) and pin (36) to the right. This moves flapper (5) towards nozzle (4), increasing the controlled valve pressure. Manual adjustment of reset screw (23) may be continued until enough additional steam has been admitted to restore the temperature to the control index.

By similar upscale pen movement, lower valve pressures may be established to reduce the steam flow, and additional reduction of steam flow may be made by turning reset screw (23) to the left.

f. THE BROWN POTENTIOMETER WITH BECK SINGLE AND TRIPLE FUNCTION CONTROL

A description of the Potentiometer Controllers and the Beck Mechanisms is as follows:

1. Description of the Potentiometer Controller

In the single point indicating or recording potentiometer controller, the resistance element is mounted on the back of the instrument frame and has a movable contact which indirectly follows the movement of the pen carriage. This action is described more fully under Proportioning Control.

The multiple point recording potentiometer with control on one point only, contains an oil-immersed selector switch which connects the thermocouples in the proper sequence for recording.

This switch has one or two more segments than the total number of points to be recorded and the control thermocouple is connected to the last two or three segments. A cam, which is mounted on the bevel gear driving the selector switch, operates a mercury control selector switch which is in series with the power supply to the proportioning relay.

The cam is designed so that the mercury switch circuit is opened when the recording thermocouples and the first segment of the control thermocouple are connected to the measuring circuit. This prevents incorrect operation of the control valve while the different temperatures are being recorded.

The mercury switch circuit is closed only when the oil switch is making contact on the second and succeeding segments of the control thermocouple. This allows the control circuit to function only when the controller has come to balance on the control thermocouple.

The resistor for the C-3 timed reset is mounted at the back of the instrument frame between the control resistor assembly and the terminal assembly.

The two-point recording potentiometer with control on both records at the same or different temperature, contains an oil-immersed switch having four segments, the first thermocouple connected to the first two segments and the second thermocouple connected to the last two segments.

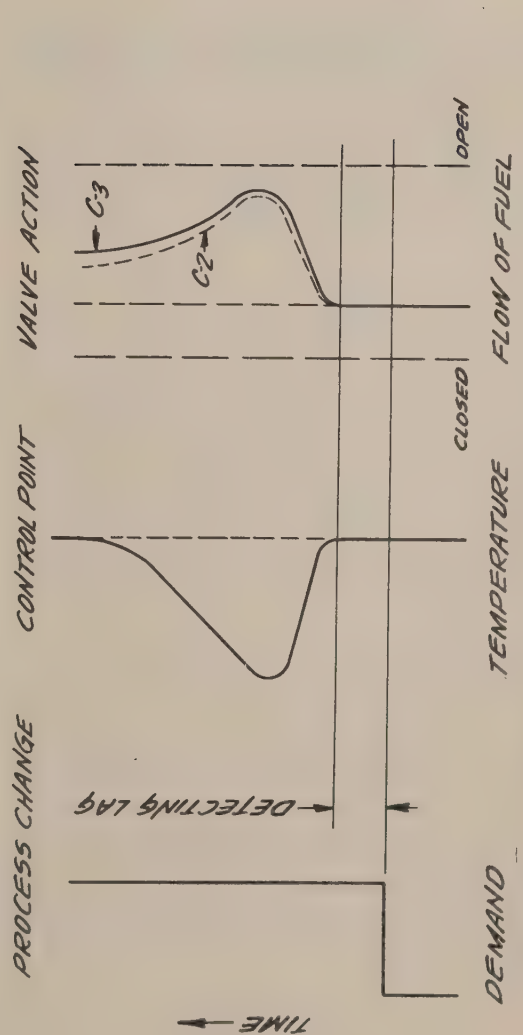
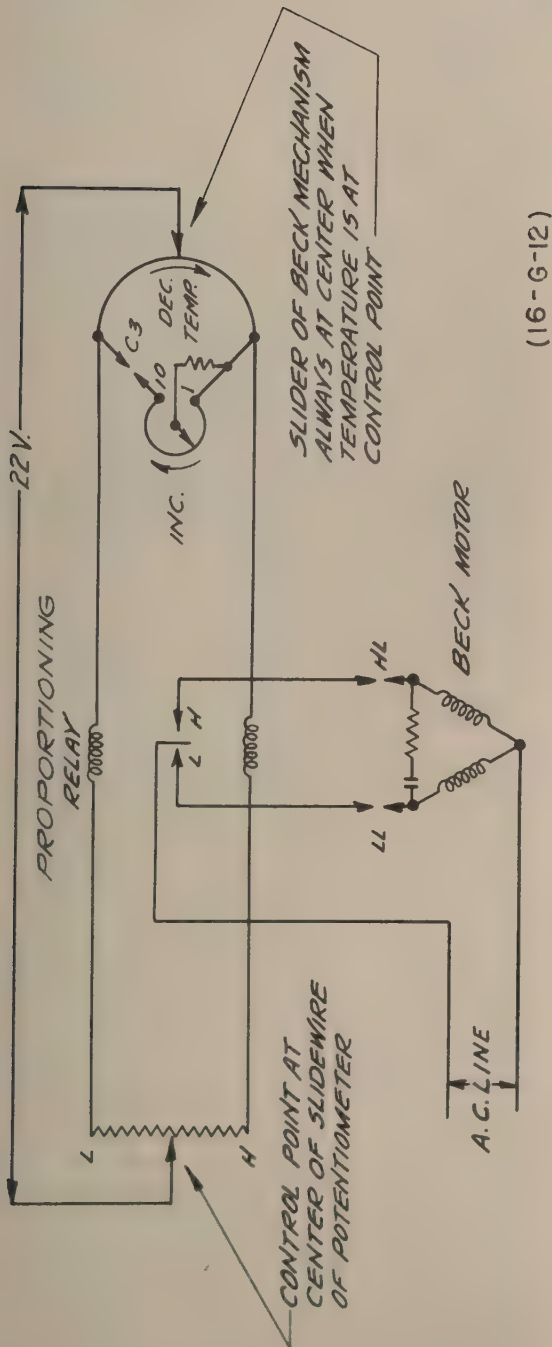
The switch action is the same as for the multiple point recording potentiometer, described above. Two resistors for the C-3 timed reset, one for each Beck Mechanism, are mounted in a separate housing.

The reset contact assembly, which is mounted on the right-hand side plate of single point controllers closes its contact for 2.5 seconds out of each 60 second cycle. With all multiple point recording controllers, a stop-cycle type cam timer is supplied. This timer replaces the C-3 reset contact of the single point controller and is required in order that the C-3 reset action may take place at the proper point in the operating cycle of the instrument. The cycle of operation of the timer is initiated by the contact of the mercury control selector switch at the same time that the proportioning control system is energized.

On multiple record controllers, the reset timer has no effect on the control circuit except when the control selector switch is closed, i.e., on the second and succeeding segments of the control record.

2. Definition of Control Actions

The various control actions are illustrated by the curves of Drawing 16-G-12. The control correction consists of three separate functions, as indicated by these curves.



CONTROL CIRCUIT OF THE POTENTIOMETER AND BECK MECHANISM

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357
Page No. 18

- C-1. Primary Control Action is proportional to the magnitude of the temperature deviation and is recovered as the temperature returns to the control point.
- C-2. Proportionate Reset is a proportionate part of the C-1 action and is permanent with respect to a given temperature deviation.
- C-3. Timed Reset is proportional to the duration of the temperature deviation and is in a direction to force the temperature toward the control point.

The solid line on the fuel rate diagram on Drawing 16-G-12 includes all three control actions and indicates the action of the control valve for a complete cycle of control.

3. Description of Beck Single Control

The electrical control circuit is shown in simplified schematic form on Drawing 16-G-12.

The control slidewire in the potentiometer is connected to the proportioning relay and the slidewire in the Beck Mechanism, forming a bridge circuit as shown, with a 22 volt a-c source of supply introduced at the sliders in the potentiometer and Beck Mechanism. When temperature is at the control point, the slider in the potentiometer is at the center of the slidewire, and for this condition, the slider in the Beck Mechanism is always in the center of the slidewire. The bridge is in balance and the proportioning relay contacts are open. The parts in the circuit are illustrated in this position.

If the temperature changes, the slider in the potentiometer moves along the control slidewire, unbalancing the bridge and causing the relay to contact high or low, energizing the Beck motor to close or open the valve, and, at the same time, to move the slider in the Beck Mechanism along a slidewire in a direction to rebalance the bridge. When the bridge is rebalanced, the relay contacts go to neutral and the Beck motor stops.

This describes the C-1 actions, producing valve motion in an amount proportional to the temperature change and in a direction to oppose the temperature change. As temperature returns to the control point in response to the change in fuel rate, the bridge circuit will become unbalanced in the opposite direction due to the slider in the potentiometer returning along the control slidewire. This will cause the relay to contact and energize the Beck motor in the

opposite direction, returning the slider in the Beck Mechanism along its slidewire back toward the center, and, at the same time, returning the valve and consequently the fuel rate back toward, but not all the way, to the value that existed previously.

4. Description of Beck Triple Function Control

a. Proportionate Reset

It is during the period in which the slider in the Beck Mechanism is returning to the center of the slidewire that the C-2 proportionate reset action takes place. The mechanical construction of the Beck Mechanism is such that the slider will return along the slidewire toward the control point faster than it departed, in relation to the speed of the valve. Thus the slidewire in the Beck Mechanism will return all the way to the control point while the valve has returned only part way back toward its original position, thus leaving part of the change in fuel rate permanent with respect to the change in temperature that caused it.

Details of the mechanical parts that cause this change in the relation of the slider in the Beck Mechanism to the position of the valve that the mechanism is operating are shown on Drawing LC-172. A full understanding of these details is probably not possible from this drawing alone, but when viewing an actual mechanism, this explanation together with the drawing, will be more clear. Referring to Drawing LC-172, the slider is carried by the yoke (87) which also carries two pawls (85) and (36). One pawl will be raised by cam (28) when temperature departs in one direction from the control point, and the other pawl will be down in engagement with the ratchet (25). When temperature departs the other way from the control point, the opposite pawl will roll up on the other end of the cam (28) and the first pawl will be down in engagement with the same ratchet (25).

The ratchet and the gear with which the ratchet is integral are driven by pinion (35) directly from the variable speed drive shown at the pinion end of the motor (75). The speed of the gear and ratchet is always faster than that of shaft (71) which turns at a fixed speed with relation to the valve operating crank (60). Shaft (71) moves the slider at the same speed that shaft (71) is turned when temperature departs in either direction from the control point, but when temperature returns toward the control point, the pawl that is

engaged with the ratchet at the time is driven by the ratchet at a speed faster than that of shaft (71) and is forced to move faster than it normally moves by friction drive from detail (39), which is fixed to shaft (71) and against which the yoke which carries the slider is pressed by spring (66).

The percent of reset established for the C-2 action is fixed to agree with the constants of the process being controlled, this setting being made manually by turning the knurled knob (95) as may be required to produce stable control to a definite temperature. Thereafter, reset action is automatic, controlling any load within the capacity of the furnace to the set control point.

b. Time Reset

The C-3 action, which is the timed reset, is produced by the combination of the electrical shunt which is periodically closed across the slidewire in the Beck Mechanism by the contact C-3 shown on Drawing 16-G-12 and the mechanical means just described for producing C-2 action. The C-3 contact closes periodically for a fixed period of 2.5 seconds, and then remains open during the balance of the cycle, which is 60 seconds total time.

This C-3 shunting action has no effect when the bridge is in balance with temperature at the control point because the bridge remains in balance whether this shunt is closed or open. This, of course, is the desired action, as no automatic reset is wanted when temperature is at the control point.

However, if the bridge is in balance with temperature at some place other than the control point, and still within the throttling range, closing of contact C-3 will unbalance the bridge again causing the Beck Mechanism to move its slider and the valve slightly in a direction that would urge the temperature back to the control point.

The amount of this motion depends upon the setting of the rheostat in the C-3 circuit marked 1-10. If this rheostat is at its extreme position in the direction marked increase, it will cause a maximum change in the resistance in the two arms of the bridge formed by the slidewire in the Beck Mechanism, and the step required to rebalance the bridge will be a maximum for a temperature deviation of a given magnitude.

The size of the C-3 step that the mechanism takes is not dependent upon the duration of closing the C-3 contact. This is an important point as it simplifies the mechanical construction of this contact, and makes the C-3 action consistent regardless of any wear on the operating cam that causes the C-3 contact to close.

When the C-3 contact is open, the Beck Mechanism moves the slider back to the position it occupied before it closed, but accompanying this C-3 step, there will have been a change in the relation of the slider to the valve in the Beck Mechanism, in a direction to urge the temperature toward the control point. A 30 ohm fixed resistor is connected into the C-3 circuit so that no adjustment of the rheostat can shunt the valve slidewire to zero.

A study of the shunting circuit described above will show that the size of the C-3 step automatically increases as the temperature departs farther from the control point, reaching a maximum when the slider in the potentiometer reaches the end of the slidewire. Thus the C-3 action changes the flow of fuel in proportion to the magnitude and duration of a temperature deviation, but the C-2 action changes the fuel an amount which is proportional only to the magnitude of the temperature deviation.

This results in stable control without sacrificing the ability in the system to quickly handle sudden changes. Control is stable because of the slowness of the timed reset C-3, and yet fast because of the character of the C-2 reset which always introduces reset as fast as the process can react, but no faster.

Another important characteristic of this system is the fact that all automatic reset stops when temperature deviates beyond the control slidewire in either direction. This renders the system capable of handling batch type heating operations successfully.

G. THE A.T.C. MECHANISMS

1. The A.T.C. Relatrol Controller

a. Description

In this type of controller all mercury switches are omitted and a 100 ohm resistance element required for the A.T.C. Relatrol Controller is substituted in the same compartment at the back of the chassis under the standard cell.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1357
Page No. 20

A sliding contactor, which takes its position from the relation of the pen with respect to the control temperature divides the resistor into two arms. As this contactor is moved over the resistance it varies the ratio of the two arms of the electrical transmission system, essentially a Wheatstone bridge. Hence there is no waiting for the making of a high, low, neutral, or some other definite control circuit before a reaction occurs at the motor driven device.

b. Operation

The temperature setting of the control point is readily adjustable by turning the small knurled knob above the door handle. Adjust the setting so the upper black index corresponds to the temperature at which control is desired. Then if the temperature changes from the control setting, the contact of the resistance element will vary its position in response to the temperature change corresponding to the pen movement on the chart.

The change in resistance will be picked up by the receiver in the motor valve and the amount of resultant correction of valve movement will be in proportion to the deviation from the control setting. A large deviation will result in a correspondingly large movement of the valve from the normal opening required to maintain the required temperature. Regulate the motor so that it has the greatest responsiveness to changes of the contact on the resistance element, and adjust the valve setting so the fuel supply is approximately that which is required to maintain the temperature at this point for normal loading and fuel conditions.

As the furnace temperature approaches the control point, the valve will gradually close, reducing the fuel input to the furnace in proportion to the difference between the temperature and the control point. This closing will continue as the control point is approached. If the temperature rises above the control point, further closing results. In other words, the control characteristic secured is that for every position of the temperature away from the control point, within the limits of the sloping control step, there is a corresponding valve position.

After opening the instrument case and swinging the frame forward, it will be seen that the stud of the connecting link is in the extreme outer hole of the lever arm operating the shaft on which the movable contact is mounted. **DO NOT CHANGE THE LOCATION OF THIS STUD.**

2. A.T.C. Balancer Controller

The operation of the A.T.C. Balancer control is similar to the A.T.C. Relatrol control and has in addition the load compensating mechanism.

It is a rotating and adjustable cam which governs the rapidity with which the corrective displacement in valve position occurs. Its function is to force the temperature to return to the control point as rapidly as possible without overshooting after any deviation.

H. THE AUXILIARY SWITCH MECHANISM

The auxiliary switch mechanism is a device for actuating a contact operation at a predetermined point on the scale in response to the position of either the pen carriage or the control carriage.

1. Description

The auxiliary switch mechanism may be mounted on either the right-hand sideplate or the left-hand sideplate of the instrument chassis.

The mechanism may have either one or two single throw switches. Therefore, the contact operation may be either SPST, SPDT, or DPST.

The switch mechanism may be driven from either the control shaft or the pen shaft. Therefore, the switch, may be operated by either the pen carriage or the control carriage as the carriage passes a certain point on the scale.

A maximum of two auxiliary switch mechanisms may be installed on the potentiometer - one on the right-hand sideplate and one on the left-hand sideplate. Each mechanism may be operated either from the control carriage or the pen carriage. Each mechanism may be SPST, SPDT, or DPST.

The switch is tilted when two slotted discs, driven by gears from the pen or control shaft, come in alignment.

2. Application

There are three general functions performed by the auxiliary switch.

First, a contact may be made above the setting of the auxiliary switch in such a manner that an alarm is rung when the temperature indicated by the pen or pointer is too high. Second the contact may be made below the setting when the temperature is too low.

Third the contact may be made when the temperature exceeds a certain limit. Thus, the control system may be shut down as a safety precaution.

1. THE INTERRUPTER SWITCH

The interrupter switch is supplied in a Brown Potentiometer Controller when a circuit is to be broken intermittently. The interrupter assembly is mounted on the right-hand sideplate.

The switch of the interrupter is rated 25 amperes at 110 volts and 15 amperes at 220 volts, and is single pole throw.

The Geneva drive for the interrupter operates from the main drive motor of the balancing mechanism. Therefore, throwing the motor toggle

switch will start and stop the interrupter as well.

If the interrupter is not connected into the control circuit inside the controller, the external wiring diagram indicates the connections to the interrupter contact.

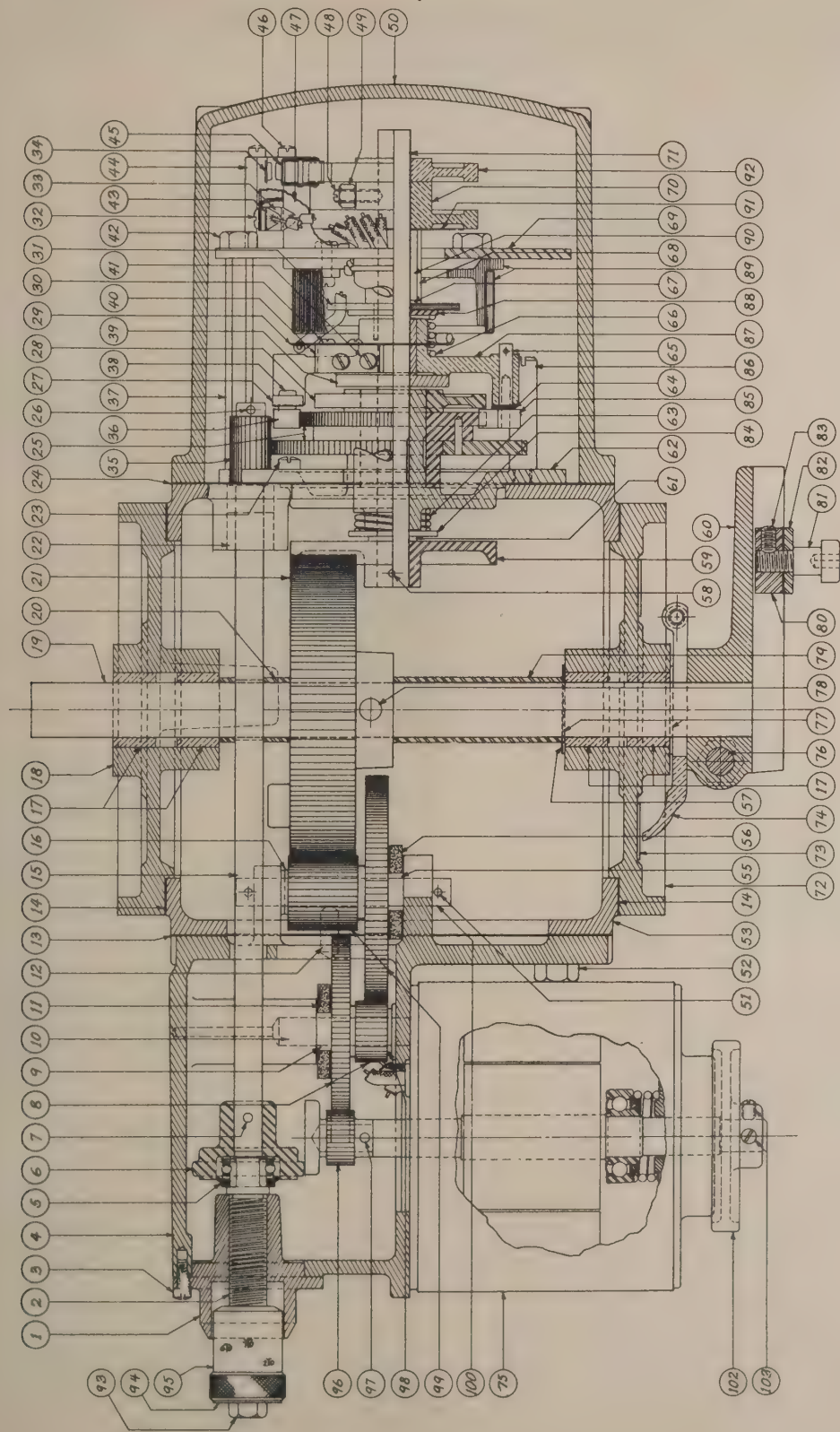
1. Characteristics of Interruption

The length of time that the contact is made may be adjusted from 1 to 7 seconds in steps of 1/2 second.

The time cycle in which the contact is made may be adjusted independently to values of 15, 30, 60, or 120 seconds.

This time includes the "on" time as well as the "off" time.

If a longer time of contact is desired, the switch may be reversed in its clip. Thus, if a 9 second contact out of 15 seconds is desired, the pin should be placed in the hole marked 6 (15-9).



DESCRIPTION OF AND DATA ON COMPONENT PARTS OF
TYPE 113 MECHANICAL POTENTIOMETER

The parts covered in this section and the order in which they occur are listed below:

- A. Measuring Circuits
- B. Slidewires and Resistance Spools
- C. Galvanometer Assembly
- D. Thermocouple Switches
- E. Current Supply for Measuring Circuit
- F. Description of Standard Cell
- G. Description of Motor
- H. Humidity Compensator
- I. Charts and Chart Reroll
- J. Pen Carriage
- K. Print Hammer Mechanism
- L. Print Wheel Mechanism
- M. Thermocouple Burn-out Safety Feature
- N. Mercury Switches

A. MEASURING CIRCUITS

The null or balance system of measurement is used in both Potentiometer Pyrometers and Resistance Thermometers. With this system the galvanometer pointer only indicates an unbalance between the thermocouple and the slidewire.

A description of the Potentiometer Pyrometer and Resistance Thermometer circuits are as follows:

1. The Measuring Circuit of Potentiometer Pyrometer

Drawing 16-G-17 shows a schematic diagram of measuring circuit number 1. Drawing 16-G-18 is the internal wiring diagram for circuits numbers 2, 3, 4, and 6. The duplex slidewire maintains a constant resistance in the galvanometer circuit so that the galvanometer sensitivity is constant for all parts of the scale. Thus, a given change in the measured emf will produce the same galvanometer deflection at any point on the scale, and the galvanometer damping characteristics remain constant for a given external resistance (thermocouple plus extension leads). With multiple recorders, the external resistance may vary, depending upon the resistance of the different thermocouples and extension leads. In such cases, the damping of the galvanometer is adjusted to the average condition, where the external resistance is unusually

high, the No. 5 spool may be shunted out to improve the damping characteristics. This will not affect the accuracy of calibration.

The cold junction compensation spool is located in the terminal plate so that it will be at the same temperature as the extended cold junction of the thermocouple.

The current drawn from the battery with this circuit is 4 milliamperes, which gives a dry cell life of about eight months.

Some ranges use a minor modification of the above circuit and also draw 10 or 20 milliamperes from the battery. Circuits II to VI have slidewires with solid returns.

Details of the various circuits applying to a given instrument may be obtained from the factory by stating the serial number of the instrument.

The following table shows details of the various potentiometer pyrometer circuits. It will be helpful in determining the type of circuit being used and the correct slidewire assemblies, cold junction spools, step tables, and galvanometers required. It will also help in locating trouble in the circuit as resistance values for various portions of the circuits are listed. Several of the resistors are not listed as their value varies, depending on the range and suppression.

Section 1358
Page No. 2

- NOTES—
1. ON SLIDE WIRES WITH SPANS ABOVE 60 MILLIVOLTS AND SLIDE WIRES WITH SAFETY FEATURE, A CONNECTION IS MADE BETWEEN THE #1 POST AND THE SHORT STUD SUCH THAT RESISTOR R_8 (1) SHUNTS THE GALVANOMETER IN ALL SWITCH POSITIONS.
 2. RESISTOR R_9 (6) IS USED ONLY ON SLIDE WIRES WITH SAFETY FEATURE.

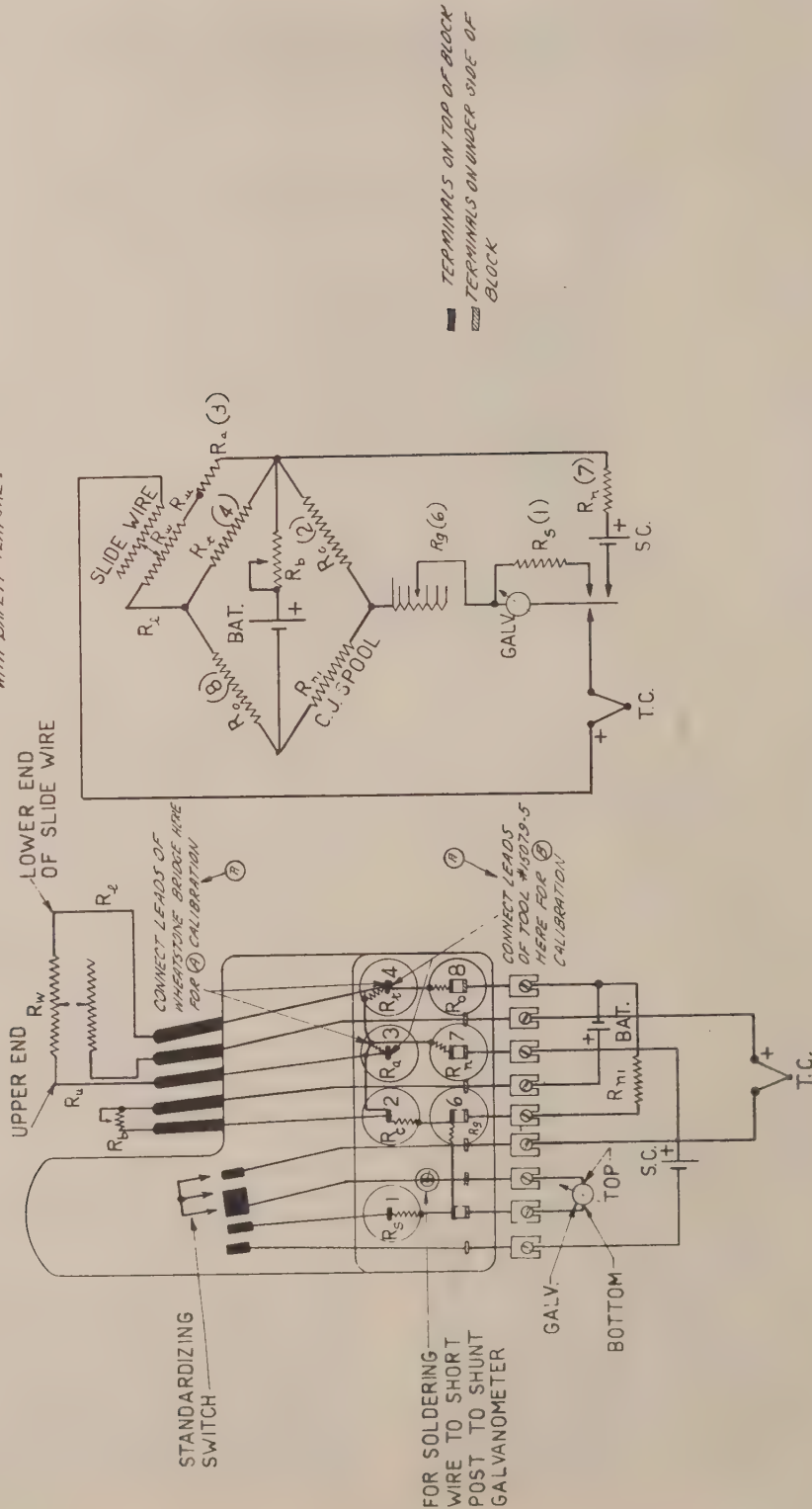
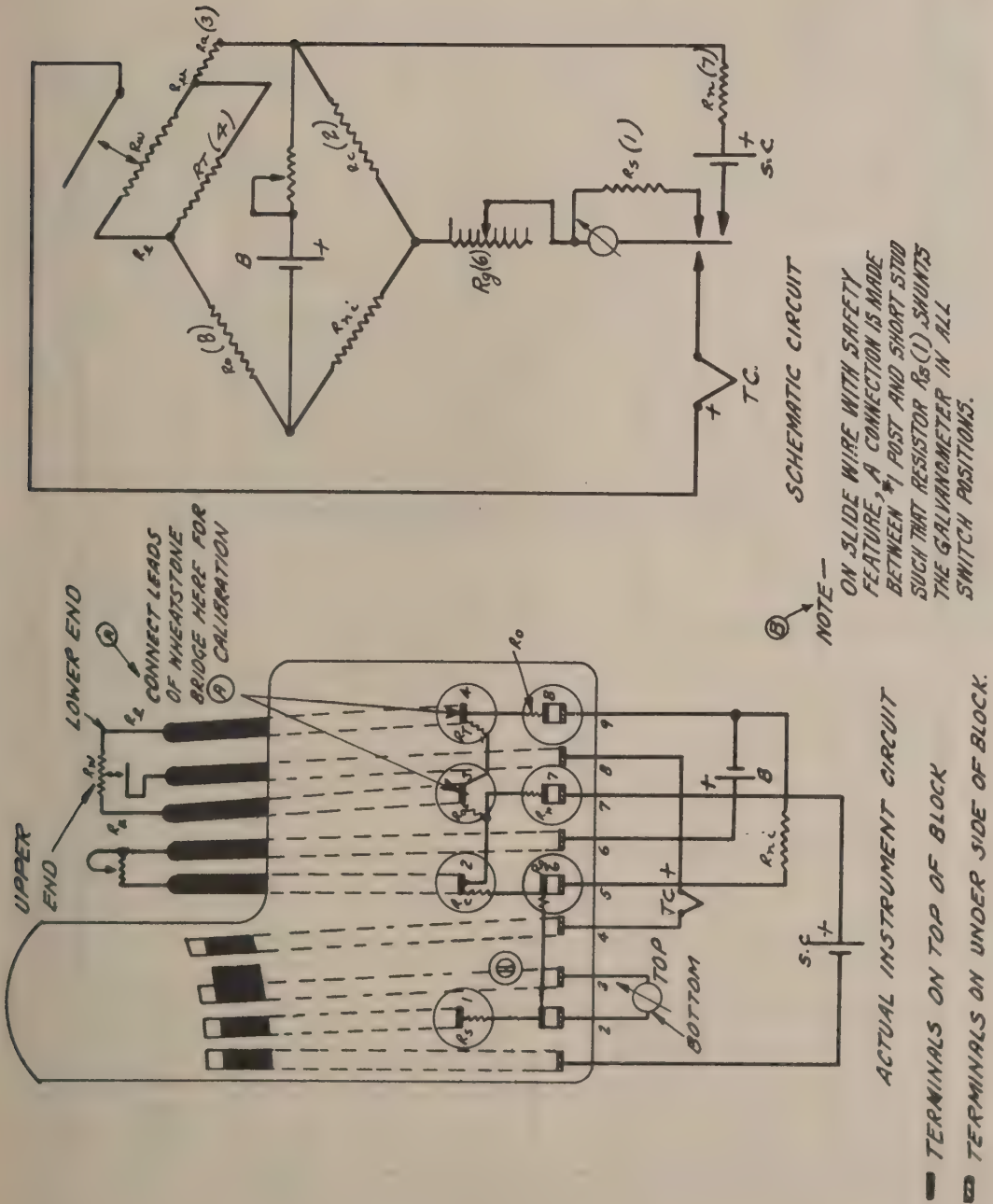


Fig. 16-G-17
SCHEMATIC WIRING DIAGRAM
RECORDING OR SINGLE RANGE INDICATING POTENTIOMETER



Drawing 16-G-18
Brown Potentiometer Pyrometer Circuit

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1358

Page No. 4

TABLE I

TABLE I																	
CIRCUIT NUMBER	TYPE OF T/C	MILLIVOLT		NOMINAL T/C CIRCUIT RES. (Incl. Gal.) (OHMS)	CIRCUIT DIAGRAMS	MAX. ALLOWABLE T/C RES. FOR MV SUPPRESSION (OHMS)										NUMBER OF DRY CELLS	BATTERY CURRENT MA
		SPAN IN MV	SUPPRESSION IN MV			0 MV	5 MV	10 MV	15 MV	20 MV	25 MV	30 MV	35 MV	40 MV			
I	↑	* 20.00 to 65.00 ** 20.00 to 65.00	up to 10.00	96	1-D-1523	18	15	13	-	-	-	-	-	-	-	1	4
II	↑	* 20.00 to 40.00 ** 20.00 to 40.00	10.00 - 40.00	96	D-2209	46	44	42	40	38	36	34	32	30		1	4
III	↑	* 8.80 to 20.00 ** 10.30 to 20.00	up to 40.00	70	D-2209	30	29	28.5	28	27.5	26.5	26	25.5	25		1	10
IV	↑	* 6.5 to 8.80 ** 8.80 to 10.30	up to 40.00	40	D-2209	6	5	4.5	4	3.5	3	2.5	2	-		1	10
V	↑	* 5.0 to 6.5 ** 6.5 to 8.87	NONE	20	D-2230	2	-	-	-	-	-	-	-	-		2 in. Parallel	20
VI	↑	* 5.00 to 20.00 ** 6.50 to 20.00	up to 12.00	20	D-2209	3	2.5	2	1.5	-	-	-	-	-		1	10

* Without Burn-out
** With Burn-out

When millivolt span is near either limit the next wider or steeper step table may give better operation.

* Without Burn-out
** With Burn-out

When millivolt span is near either limit the next wider or steeper step table may give better operation.

TABLE II

TABLE II															
CIRCUIT NUMBER	SLIDING ASSEMBLY			COLD JUNCTION RESISTORS						RESISTANCE IN OHMS					*A* VALUE IN OHM RES.
	MECHANICAL BALANCE	MANUAL BALANCE	DESCRIPTION	MA	IC	MV	QR	HER	CC	R _n	R _c	R _b	R _s	R _g IN STEPS OF APPROX. 6 OHMS	
I	*	150 79-Range		Duplex approx. 40 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	800	509.5	-	△	NONE	A=.5(10 194MV - MV + .0053 MV _S)
	**	170 11-Range	74749-Range							600	509.5	-	70	6.2 to 18.0 4 steps	
II	*	17785-Range		Solid Return approx. 20 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	800	509.5	-	70	8.2 to 47.0 in 6 steps	A=.5062MV _S
	**	17787-Range	74748-Range							600	509.5	-	70	6 steps	
III	*	17060-Range		Solid Return approx. 20 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	1200	509.5	-	55	6.2 to 36.0 in 6 steps	A=.1266MV _S
	**	17653-Range	74747-Range							1200	509.5	-	55	6 steps	
IV	*	170 60-Range		Solid Return approx. 20 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	400	509.5	-	20	1.0 to 6.2 in 6 steps	A=.1266MV _S
	**	17653-Range	74747-Range							600	509.5	-	20	6 steps	
V	*	17781-Range		Solid Return approx. 20 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	400	509.5	50	11	1.0 to 6.2 in 6 steps	A=.07234MV _S
	**	17783-Range	17781-Range							600	509.5	50	11	6 steps	
VI	*	170 60-Range		Solid Return approx. 20 ohms	Section I to IV 15266 (MA) 4.705 ohms at 75°F	Section I to IV 15267 (IC) 6.025 ohms at 75°F	Section I to IV 15247 (MV) 4.705 ohms at 75°F		Section I to IV 15266 (MA) 4.705 ohms at 75°F	400	509.5	-	11	1.0 to 6.2 in 6 steps	A=.1266MV _S
	**	17653-Range	74747-Range							600	509.5	-	11	6 steps	

△ Un spans about 60 MW connect R_g permanently across the galvanometer on all instruments without burn-out feature. Refer to wiring diagram for terminals to which the Wheatstone bridge is to be connected for checking the A Res. value.

* Without Burn-out Feature
** With Burn-out Feature

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1358

Page No. 6

TABLE III

TABLE III					
CIRCUIT NUMBER	STEP TABLES			GALVANOMETERS	
	NUMBER	SPAN IN MV			
		WITHOUT BURN-OUT	WITH BURN-OUT	MECHANICAL BALANCE	MANUAL BALANCE
I	40602	20.0 to 32.0	20.0 to 39.0	15398	15665
	40091	32.0 to 65.0	39.0 to 65.0	1 red dot	1 red dot
II	40602	20.0 to 32.0	20.0 to 40.0	15398	15665
	40091	32.0 to 40.0	-- --	1 red dot	1 red dot
III	40601	8.8 to 13.1	10.3 to 15.5	15398	15665
	40602	13.1 to 20.0	15.5 to 20.0	1 red dot	1 red dot
IV	40601	6.5 to 8.8	8.8 to 10.0	17070	15665
	40602	-- --	-- --	1 green dot	1 red dot
V	40601	5.0 to 6.5	6.5 to 8.87	17069	17260
				1 blue dot	1 green dot
VI	40601	5.0 to 8.0	6.5 to 8.7	17069	17260
	40602	8.0 to 14.0	8.7 to 15.5		
	40091	14.0 to 20.0	15.5 to 20.0	1 blue dot	1 green dot

NOTE: When millivolt span is near either limit the next wider or steeper step table may give better operation.

2. The Measuring Circuit of the Balanced Wheatstone Bridge Resistance Thermometer

Drawing 16-G-19 shows a schematic diagram of the measuring circuit, which consists of a slidewire, galvanometer, bulb, battery, and resistors connected in the form of a Wheatstone bridge.

The bulb is a coil of nickel wire mounted in a suitable protecting tube with terminal head. The resistance of the nickel wire varies with the temperature surrounding it, in accordance with definite physical laws and can be used as a measure of temperature.

The circuit is so designed that when the resistance of the bulb is equivalent to the minimum temperature of the range, the bridge is balanced (galvanometer deflection is zero) when the slider is at the lower end of the slidewire. Conversely, when the resistance of the bulb is equivalent to the maximum temperature of the range, the bridge is balanced when the slider is at the upper end of the slidewire.

When a temperature change at the bulb causes a corresponding resistance change, the bridge becomes unbalanced and the galvanometer pointer deflects. The instrument mechanism functions to move the slider so as to restore the electrical balance. When the galvanometer deflection becomes zero, indicating electrical balance, the mechanism ceases to function, and the position of the slider on the slidewire is an indication of the temperature of the bulb.

A pointer or pen connected with the slider and moving with it, travels over the scale or chart, graduated in terms of temperature.

Since the circuit is normally balanced, the position of the slider, and therefore, the accuracy of the instrument is independent of the battery current and voltage, hence the lack of necessity for standardizing the battery current as in a potentiometer.

The slidewire used with Resistance Thermometers and data regarding resistance values, number of cells, step tables, and scales are listed in table number 4.

8. SLIDEWIRES AND RESISTANCE SPOOLS

The slidewire is the variable resistance in the potentiometer circuit. The assembly is built upon a bakelite molding and carries the entire electrical circuit of the potentiometer with the exception of the nickel cold junction compensating coil and the interconnecting cables.

The slidewire, Figure 1358-1, is over 40" long and is laid in a groove parallel to either a return solid conductor or a wound resistance wire similar to the slidewire resistor which is connected to the thermocouple and galvanometer. The return conductor eliminates the necessity of using a flexible connection.

The 40" slidewire has 1600 convolutions which means that 1600 possible balancing points are provided over the range of the instrument. This is practically the equivalent of a continuous wire. Each convolution represents about .06% of full scale range. The slidewire is made of bare manganin wire space wound on a No. 10 gauge copper Formex insulated core. With a long slidewire, the wire can be of larger diameter, and any wear which occurs in time will have less effect on the accuracy. Calculations will readily show that a larger resistance wire, wound on a proportionally larger core (as is evidently proper in consideration of the distortion produced in wire wound into small helices) will give more convolutions and a longer finished slidewire, with less resistance, than can be obtained by using small wire wound on a small short core. The larger diameter resistance wire wound on a larger core has the further advantage that wear produced by the sliding contactor has very much less effect upon the slidewire resistance; 1st, because more metal has to be removed for a certain depth to be reached thus the progress is slower; 2nd, because wear to a given depth affects the cross-sectional area of the wire less; and 3rd, because the larger core wire confines the worn section to a smaller fraction of the total length of the resistance wire. The large diameter wire also enables the contacts to be broad, with a good bearing surface.

The contactor consists of a short cylinder made of a special silver alloy somewhat softer than the resistance wire used in the slidewire so that if any wear does occur, it will be on the contactor which is readily replaced. The contactor material has been chosen because of its physical and electrical properties. 5-1/32 revolutions of the slidewire shaft move the contactor from one end to the other of the slidewire.

The slidewire is enclosed in a glass container and is usually immersed in oil. It is designed for oil immersed operation. No corrosive gases, fumes, etc., usually present in manufacturing plants, can come in contact with the slidewire. The slidewire and contacts are constantly washed clean and lubricated in the special oil which cuts down the wear on both the slidewire and the contactor.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

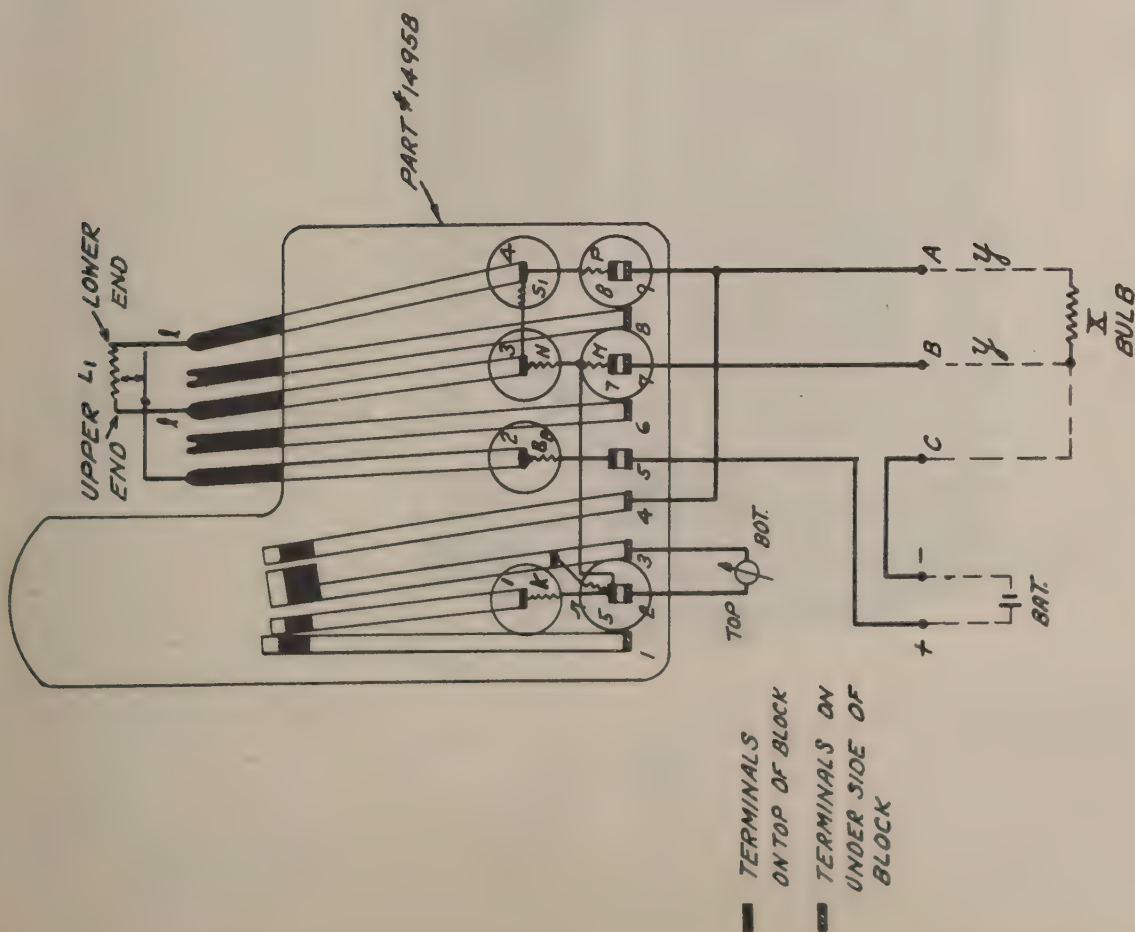
Section 1358

Page No. 8

TABLE IV

RECORD NO.	RANGE	BULB	RECORDER AND AUTO. BAL. INDICATOR SCALE NO.	MAN. BAL. INDICATOR SCALE NO.	SLIDE WIRE 15482-	GALVANOMETER		STEP (TABLE ONLY)	NO. OF DIVISIONS	K	R _B	N	A	r	M	P	CURRENT (DRAIN (AMPS.))	LEAD RES (OHMS)	TAP SETTING ON 73787 RECTIFIER
						RECORDER	INDICATOR												
5900	-40 to +40°F	A	77078-5900	65900	5900	15398	15665	40601	2	410	97	347.01	40	48	466.00	346.24	0.0054	2.5	3
5901	0 to 100°F	A	77078-5901	65901	5901	15398	15665	40601	2	376	186	294.68	40	48	530.00	294.06	0.0046	2.5	3
5902	-60 to +120°F	A	77078-5902	65902	5902	15398	15665	40602	2	328	204	150.60	40	52	500.00	149.81	0.0044	2.5	3
5903	0 to 150°F	A	77078-5903	65903	5903	15398	15665	40602	2	312	202	196.93	40	50	565.00	195.19	0.0057	2.5	3
5904	0 to 220°F	A	77078-5904	65904	5904	15398	15665	40601	2	345	97	133.99	40	52	610.00	132.68	0.0058	2.5	3
5905	100 to 320°F	A	77078-5905	65905	5905	15398	15665	40601	2	414	140	277.54	40	48	689.00	276.33	0.0044	2.5	3
5906	0 to 250°F	A	77078-5906	65906	5906	15398	15665	40602	2	226	394	118.23	40	53	635.00	115.89	0.0036	2.5	3
5907	0 to 300°F	A	77078-5907	65907	5907	15398	15665	40601	2	200	122	98.56	40	55	675.00	95.42	0.0054	2.5	3
5908	90 to 110°F	A	77078-5908	65908	5908	15455	15673	40600	2	600	36	498.09	12	20	600.00	498.24	0.0049	2.5	3
5909	60 to 80°F	A	77078-5909	65909	5909	15455	15673	40600	2	520	67	481.58	12	2480	559.00	481.14	0.0047	2.5	3
5910	40 to 120°F	A	77078-5910	65910	5910	15455	15673	40601	2	477	23	390.22	40	none	572.00	389.45	0.0054	2.5	3
5911	-20 to +130°F	A	77078-5911	65911	5911	15398	15665	40601	2	329	399	221.22	40	49	525.00	219.27	0.0036	2.5	2
5912	-60 to +60°F	A	77078-5912	65912	5912	15398	15665	40601	2	322	326	227.03	40	50	470.00	223.59	0.0041	2.5	2
5913	85 to 145°F	A	77078-5913	65913	5913	15398	15665	40600	2	267	97	164.38	12	51	622.00	164.16	0.0056	2.5	3
5914	225 to 375°F	A	77078-5914	65914	5914	15398	15665	40601	2	249	191	133.69	22	52	925.00	133.23	0.0039	2.5	2
5915																			
5916																			
5917	10 to 40°F	A	77078-5917	65917	5917	15455	15673	40601	2	505	166	493.08	20	2900	498.00	493.18	0.0045	2.5	3
5918	-25 to +5°F	A	77078-5918	65918	5918	15455	15673	40601	2	472	393	473.21	20	none	454.00	472.54	0.0042	2.5	3
5919	-144.22 to +96.89°F	A	77078-5919	65919	5919	15398	15665	40602	2	226	394	118.23	40	53	635.00	115.89	0.0036	2.5	2
5920	15 to 75°C	A	77078-5920	65920	5920	15398	15665	40601	2	140	251	74.01	10	62	622.00	73.36	0.0046	2.5	3
5921	-20 to 120°F	A	77078-5921	65921	5921	15398	15665	40602	2	318	128	206.24	40	50	535.00	202.82	0.0055	2.5	3
5922	+50 to 130°C	A	77078-5922	65922	5922	15398	15665	40601	2	460	46	316.06	40	47	716.00	313.95	0.0049	2.5	3
5923	-80 to +140°F	A	77078-5923	65923	5923	15398	15665	40602	2	221	417	122.54	40	53.5	515.13	117.06	0.0036	2.5	2
5924	100 to 150°C	A	77078-5924	65924	5924	15398	15665	40601	2	191	968	102.04	10	55.5	850.00	101.58	0.0019	2.5	2
5925	440 to -30°C	A	77078-5925	65925	5925	15455	15673	40602	2	505	270	440.37	40	2900	553.00	438.30	0.0036	2.5	4
5926	+30 to 100°F	A	77078-5926	65926	5926	15455	15673	40601	2	564	22	535.80	20	1840	566.00	535.04	0.0048	2.5	4
5927	+60 to 90°F	A	77078-5927	65927	5927	15455	15673	40602	2	560	74	548.74	40	1850	546.00	546.98	0.0053	2.5	3
5928	0 to 25°F	A	77078-5928	65928	5928	15398	15665	40602	2	292	45	172.34	40	50	639.00	168.39	0.0057	2.5	2
5929	0 to 100°C	A	77078-5929	65929	5929	15398	15665	40601	2	177	677	88.86	40	57	551.00	81.67	.0028	2.5	2
5930	-100 to +200°F	A	77078-5930	65930	5930	15398	15665	40602	2	177	677	88.86	40	57	551.00	81.67	.0028	2.5	2
5931	-40 to +60°C	A	77078-5931	65931	5931	15398	15665	40602	2	233	250	155.52	40	51	530.00	153.64	0.0046	2.5	3
5932	-40 to +100°C	A	77078-5932	65932	5932	15398	15665	40601	2	214	112	111.59	40	54	580.00	108.78	0.0060	2.5	3
5933	0 to 150°C	A	77078-5933	65933	5933	15455	15673	40602	2	193	393	113.67	40	53	700.00	111.15	0.0035	2.5	2
5934	-25 to +225°C	D	77078-5934	65934	5934	15455	15673	40601	2	600	191	767.08	40	1600	140.00	765.68	0.0034	2.5	2
5935	0 to 150°C	Spec.	77078-5935	65935	5935	15398	15665	40602	2	159	423	169.43	40	59	140.00	164.92	0.0048	2.5	2

Refer to Engineering Department



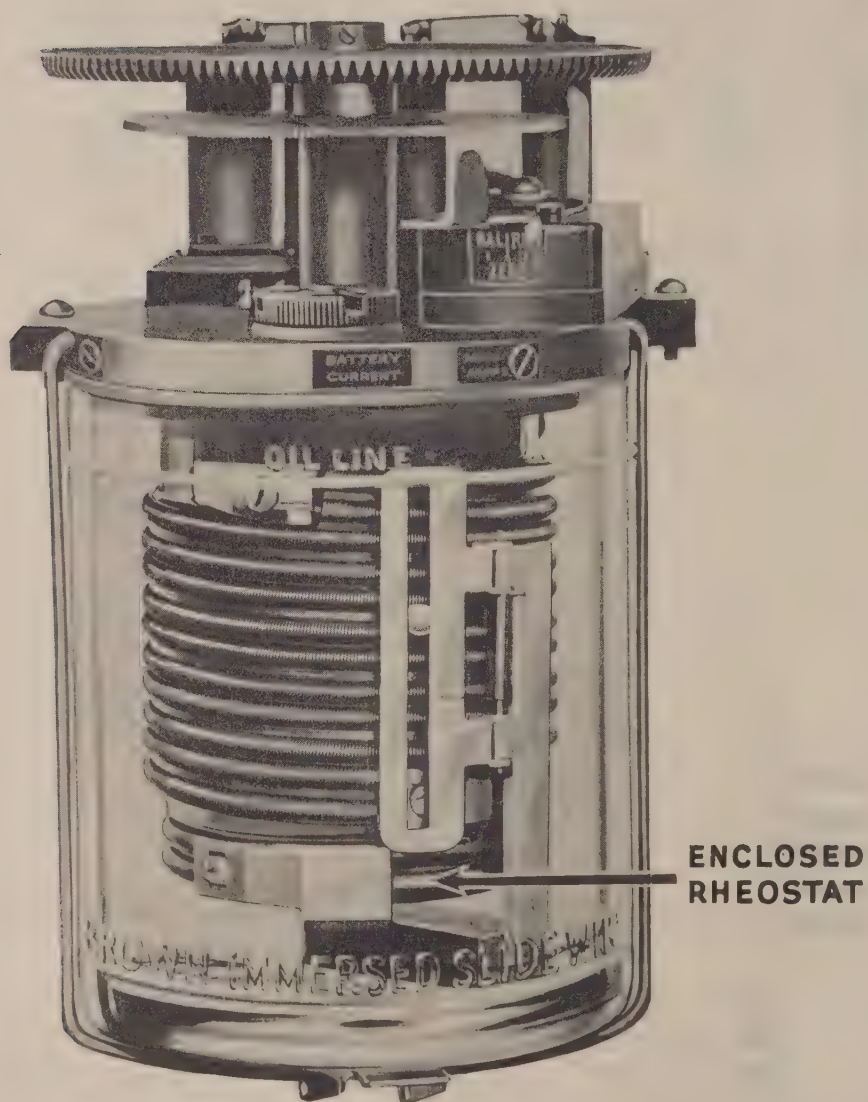


Figure 1358-1
Slidewire Unit

A rheostat for balancing the battery against the standard cell is shown in Fig. 1358-1 below the main slidewire. This is operated from the solid gear shown below the large aluminum bevel gear at the top of the figure. The handle for operating a switch for use in the standardizing and mechanical balancing operations is shown immediately below the right-hand side of the solid gear. The switch contacts are placed inside a bakelite housing as shown. This switch is of the three-leaf type, sliding diagonally across switch contacts that protrude from the bakelite molding which forms the base. All the conductors, including the switch connections, are composed of metal strips and rods moulded into the bakelite form. Some of these extend upward to form both leads and supports for the spools.

C. GALVANOMETER ASSEMBLY

The galvanometer is of the suspension type and is entirely enclosed in its own housing inside the instrument case. Figure 1358-2 is a photo of the galvanometer assembly removed from the housing. Its movement can be observed through a removable window in the front of its cover. This covering can be instantly removed without removing a single screw and without tools. It consists of a metal back plate, bakelite cover, and window. Spring clips on the metal back plate and on the frame around the window hold the cover in place. The cover protects the galvanometer from mechanical injury and from dirt, dust, and fumes and prevents air currents from upsetting the operation of the instrument when the case is opened for changing charts, making notes on the record, etc., or when the hinged frame is swung out for inspection.

This galvanometer is designed to a uniformly high responsiveness under all practical operating conditions. The balancing mechanism exerts no strain upon the galvanometer pointer because the pointer and suspensions are relieved of practically all work by the introduction of a "secondary pointer" system, wherein a rugged secondary pointer assumes a position in magnified proportion to the galvanometer pointer position and then governs the adjustment of the pen and the slidewire contact. The mechanical movements of the secondary pointer are comparatively large. As a result, no adjustments are needed to take up wear on either the pointer or the contacting mechanism and the highest accuracy is maintained over long periods of continuous operation.

Three types of coils, similar in appearance but having different windings and consequently different characteristics, are furnished for the three different measuring circuits used, requiring battery currents of 4, 10, and 20 milliamperes

The pointer is comparatively long and is so designed in order to amplify the coil movement so that comparatively wide steps on the step table can be used for small movements of the coil.

The step table mechanism which contacts with the pointer is placed inside the galvanometer housing and is operated by a horizontal shaft entering through the right side. This mechanism is moved upward by a light spring when permitted by the right-angle end of the horizontal shaft called the table lever shaft. The effort required to oscillate this mechanism is so slight that the step table is brought against the galvanometer pointer with a force of only a few grams, thus greatly prolonging the life of the pointer tip. The step table rises until one or the other of its steps comes to rest against the galvanometer pointer. In its upward motion, the step table has a series of possible stopping places, one or the other of which is selected according to the deflection of the galvanometer pointer. This step table, then, positions the table lever shaft, which positions the table lever, which is on the inside of the right-hand sideplate and extends through the sideplate to position the secondary pointer.

The steps on the step table are steeper in the middle than at the ends, with the result that very slight deflections of the galvanometer pointer away from the middle or neutral step will produce substantially large and definite differences in the secondary pointer position. As the step table steps become wider at greater distances from the neutral step, the magnification of the secondary pointer motion diminishes, making it possible for the largest steps of the pen to be eighty times larger than the smallest one. For narrow ranges, a step table is used which has steps of the same height as those used for wider ranges, but having narrower faces, making steeper steps. With such a steep step table, the instrument will operate with the same large steps although the galvanometer deflection is less.

The galvanometer pointer projects through two rectangular openings, one of which is fixed and the other movable. The upper edge of the rectangular opening in the fixed piece is known as the upper clamping bar. The lower edge of the rectangular opening in the movable piece is known as the lower clamping bar. The upper edge of the rectangular opening of the movable piece is known as the stripper bar.

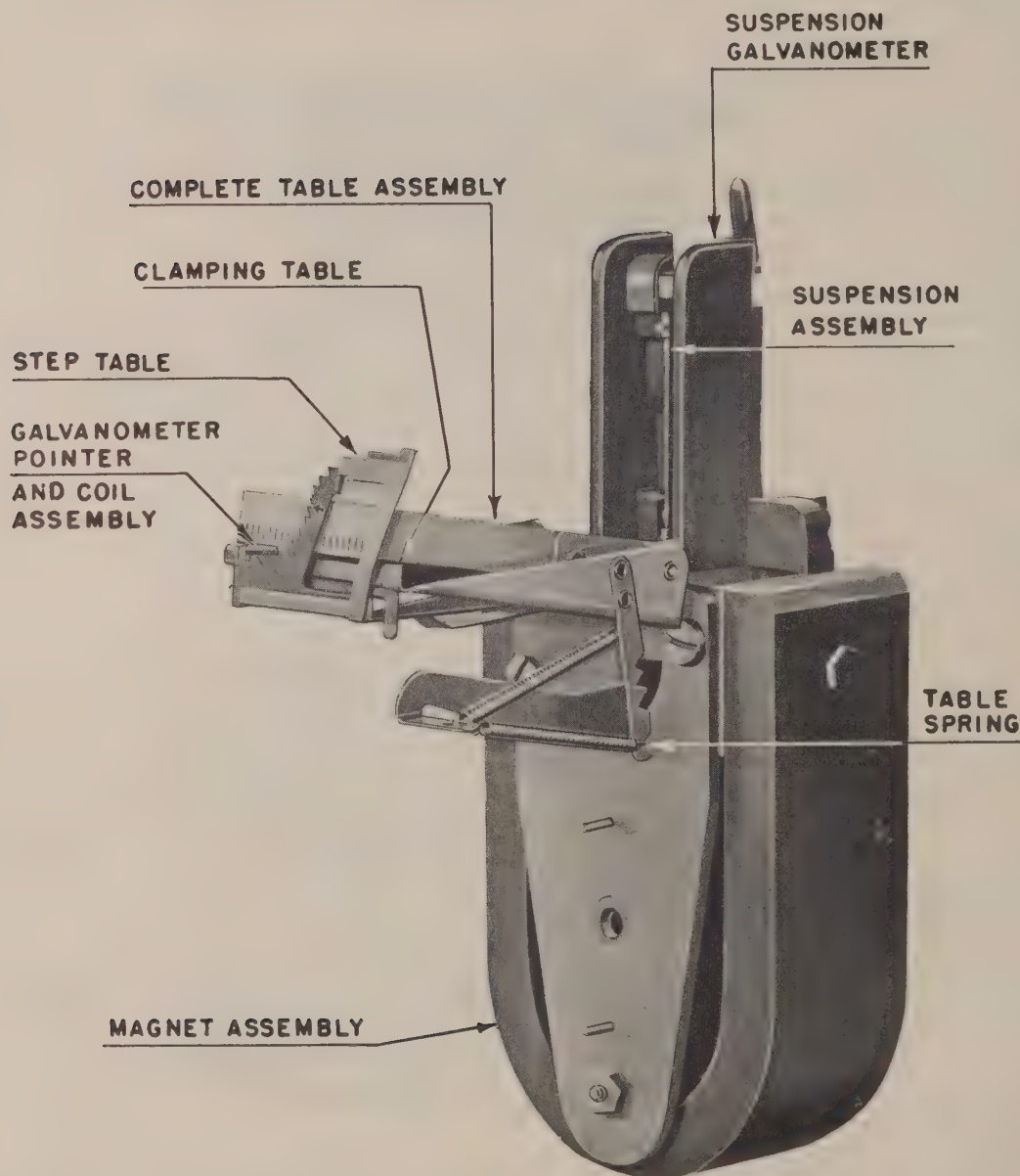


Figure 1358-2
Galvanometer Assembly

An ear on the upper right-hand corner of the step table contacts a projection on the movable piece during the downward motion of the step table and pulls the movable piece down until in its final position the stripper bar is 0.025" below the upper clamping bar. This is done so that the galvanometer pointer cannot stick to the upper clamping bar. This distance of 0.025" is obtained by adjustment of the ear of the step table. In its upward movement, the step table first allows the lower clamping bar to clamp the pointer lightly but positively between the lower clamping bar and the upper clamping bar, and then the step table itself comes up to take its position from the position of the galvanometer pointer. There is no possibility that the pointer can move away from its proper position.

1 Data

There are four types of galvanometers for use with the various ranges. The following table lists the part numbers, resistance of the coil, and color coding for identification.

GALVANOMETER PART NUMBER		COLOR CODING	NOMINAL RESISTANCE OF COIL PLUS SUSPENSION IN OHMS
MECHANICAL BALANCE	MANUAL BALANCE		
15398	15665	RED	28
15455		YELLOW	200
17069		BLUE	8
17070	17260	GREEN	21

D. THERMOCOUPLE SWITCHES

1. Description

The thermocouple switches have brass contacts and phosphor bronze brush fingers. The switch base is designed so the contacts can be covered to a depth of 1/16" with the Brown Instrument immersion oil. The switches are driven and indexed properly by a Geneva gear.

Two types of switch assemblies are used, the difference being, in the mounting bracket, in the ratio of the drive gears and the addition of the record indicating dial used on the print hammer instrument. These two types of switches are not interchangeable, due to the difference in the ratio of the switch driving gears.

E. CURRENT SUPPLY FOR MEASURING CIRCUIT

Two types of current supply are available for use with the Brown Potentiometer Pyrometer. They are: (1) carbon cells; (2) dry cells.

The number of cells to be used depends upon the current requirements of the circuit.

The battery current required to operate a Potentiometer Pyrometer is stated on the slide-wire nameplate.

The dry cell consists of a hollow zinc cylinder, which is the negative pole, and a carbon rod, which is the positive pole. The electrolyte is a paste of sal ammoniac. The space between the carbon and zinc is filled with a mixture of granulated carbon and manganese-dioxide, the latter being the depolarizer. In new cells the open circuit emf is between 1.5 and 1.6 volts.

Dry cells should be mounted in a location free from moisture and excessive heat or cold. Large temperature variations at the cell should be avoided for best instrument operation. The center terminal of the cell is positive (+) and the outside terminal is negative (-).

Except in the Manual Balance Indicator, space is provided inside the instrument for one dry cell. Where more than one cell is required, the cells must be located external to the instrument.

A special battery container can be supplied. It should be placed in the thermocouple lead conduit with its removable cover accessible from the left side of the instrument. When a group of instruments is to be mounted close together in a row, the dry cell container should be located above or below the instruments so the covers can be removed from the front. When the instrument is flush mounted on a panel, the dry cell container is located in the thermocouple lead conduit at the back of the instrument.

The proper number of cells to be used for a given instrument is covered in the following table:

CELL REQUIREMENTS FOR BROWN POTENTIOMETERS		
CURRENT RE- QUIREMENT (MILLIAMPS)	NO. OF DRY CELLS	NO. OF CARBON CELLS
4	1	1
10	1	1
20	2	2

where 2 cells are used connect them in series.

F. DESCRIPTION OF STANDARD CELL

In the actual process of measurement, the unit or standard which is used for comparison must be a definite, unchangeable thing. The need of a standard emf was recognized in the early days of the electrical industry. The type of cell most generally used for this purpose at the present time is the Weston or cadmium cell, which possesses to a great degree the necessary characteristics of permanence and reproducibility.

The particular type of cell used in the Brown potentiometer is known as the unsaturated acid type, which has a solution that is saturated at 4°C. and a voltage that does not vary to any appreciable extent with temperature changes within the usual operating range. This cell is usually accompanied by a certificate stating its exact voltage, which at 20°C is between 1.0185 and 1.0195 volts. With the electrolyte slightly acid, the cell has a lower voltage, which depends on the acidity, but shows no perceptible change with age.

The standard cell consists of a glass container shaped like the letter "H" and suitably mounted on a bakelite plate provided with binding posts to which platinum lead wires are attached. Cadmium amalgam is used for the negative pole, pure mercury for the positive pole (the heavier of the two legs) and cadmium sulphate for the electrolyte. The particular advantage in the use of cadmium arises from the low temperature coefficient and small temperature lag thus obtainable. It also has a longer life and polarizes less rapidly. Polarization is the name applied to the changes produced in the relative concentrations of the electrolyte at the two poles of a cell or to the production at the poles of new chemical substances (such as hydrogen) as a result of the flow of current through it. Polarization always tends to reduce the effective emf of the cell.

No appreciable current can be taken from a standard cell without altering its emf, due to polarization. It is found that the change is not permanent, for the cell gradually recovers its original emf; of course, the cell is unreliable until the recovery is complete. Theoretically, the life of a cell is unlimited, but actually, because of the slight drain while balancing, the cell has a useful life span which is normally many years. The key which closes the standard cell circuit should be used only momentarily.

G. DESCRIPTION OF MOTOR

Where alternating current (a-c) service is available, which represents 95% of the instrument service in the United States, a synchronous capacitor type motor without brushes or (centrifugal switch) is used, eliminating possible trouble with brush and commutator contacts, arcing, and speed governors.

The speed of a synchronous motor depends solely upon the frequency of the power plant generator supplying electric energy to it, rather than the voltage. Hence, normal load and voltage variations within 10% of the rated voltage have no effect. The motor is therefore said to run in synchronism with the source of supply and is called a "synchronous" motor.

The motor has a speed of 1800 RPM at 60 cycles or 1500 RPM at 25 cycles, which, through a gear reduction unit, is reduced to 16-2/3 RPM at the output shaft. A constant speed motor is necessary so that the chart keeps accurate time.

D-c motors are also supplied. These are necessarily brush type motors. The speed depends directly upon the line voltage.

Variations in d-c voltages in industrial plants frequently make it difficult to obtain proper chart timing.

The gear reduction unit is built into the motor bonnet and is packed in grease, as are also the ball bearings of the motor. This type of construction requires a minimum amount of attention. Each instrument is supplied with a toggle switch in the motor circuit so that the motor can be stopped at any time, for instance while the mechanism of the instrument is being observed. The motor is held in position by four screws. It is connected to the electrical circuit by a separable coupling so that the motor can be removed from the instrument by merely taking out the four screws.

The flexible shaft which is used as a universal coupling between the motor and kidney cam is made of three layers of wire, wound in opposite directions, with a fitting on each end containing a plate clamp for fastening to the motor and kidney cam shafts. The plate should be clamped tight on the shaft, otherwise backlash in the kidney cam will cause a knock or jump in the step lever.

H. HUMIDITY COMPENSATOR

A humidity compensating strip is used on pen dragging and print hammer type instruments. The position of the pen and print hammer indicates the correct temperature reading and is not affected by changes in humidity. It is known that the best available papers for making roll charts expand or contract as the humidity changes. In order to minimize the effect of this condition, charts are printed under conditions of controlled humidity, insuring uniformity of expansion and contraction among all charts.

On instruments using the ink pen, a humidity compensator has been added to give the highest degree of precision in following the time-temperature curve of a single process. This is shown in Figure 1358-3.

mer in direct proportion to the extent of the expansion or contraction of the chart, without moving the pen carriage. The movement is always proportional to the position of the pen with respect to full scale on the chart because it is accomplished through the angularity of the compensator bar which causes minimum movement at the upper end of the chart where the paper and bar are pivoted and where the least change occurs, and maximum movement at the lower end where the greatest change occurs.

The humidity compensator bar is parallel with the line of travel of the pen carriage and is directly back of the scale plate.

The extent of backward and forward motion of the bar is proportional to the distance from its pivoted end and accordingly the motion of

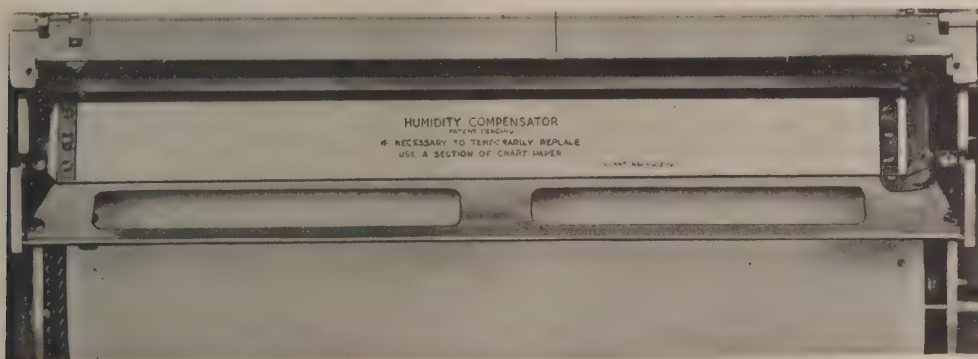


Figure 1358-3
Humidity Compensating Strip

This compensator consists of a strip of paper similar to the chart paper which is fastened at the right-hand side of the instrument, under the writing platen, close to the chart paper and free to move longitudinally at the left-hand side.

When the length of the paper strip changes due to a change in relative humidity, the movement is transmitted by linkage to the compensator bar which is always in contact with a small bell crank lever on the pen carriage.

The humidity compensator strip is held under tension by a small spring on the left-hand end of the compensator bar. The strip and the bar are connected by a simple lever system. A movement of the compensator bar causes a movement of the bell crank lever on the pen carriage, which causes a movement of the pen or print ham-

mer in direct proportion to the expansion and contraction of the strip chart at all points across the chart. The pen is thus moved the proper distance to insure proper registry between the pen and the chart under all conditions of humidity.

I. CHARTS AND CHART REROLL

Every chart roll is 125 feet long and, at the standard rate of travel found most satisfactory, 2" per hour, the chart will last 31.5 days of continuous day and night operation. The chart is 12" wide with a distance of 11" between the upper and lower lines. Time markings are printed at 2" intervals, while the temperature scale is printed at 3" intervals.

A reroll for the chart paper which will reroll an entire roll of chart paper inside the instrument is supplied in each instrument. The

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1358

Page No. 16

chart feeds from the driving roll and folds in the bottom of the case when the reroll is not used. When allowed to fold in the bottom of the case, it is only necessary to remove it every two days. Whether the reroll is used or not, 8" of chart paper is visible at all times.

The reroll operates from a chain drive on the left-hand end of the chart drum, through a friction drive onto the reroll tube. This friction drive is provided so that, as the diameter of the rerolled chart increases, a slippage of the friction drive allows the increased peripheral speed to be taken care of so that the reroll does not pull the chart off the pins on the driving drum.

J. PEN CARRIAGE

The pen carriage is provided with either a V spring or a split nut which contains a spiral thread which rides in the V notch of the spiral shaft. The split nut takes up all play so that backlash can not develop.

The cradle which holds the glass pen is held in place by V notches in the pen carriage. These notches allow the pen to be removed easily. The notches also act as pivots. They are on the axis of the ink container so that the pen pressure on the chart does not vary with the quantity of ink in the pen. They also insure the pen registering with the proper chart line when the pen is replaced after filling. When the pen carriage moves to the upper end of its travel, the pen should be in register with the upper line on the chart. If this registry does not exist, a slight bend of the left-hand end of the penholder will remedy this condition, since the cradle into which the glass pen fits is positioned by the groove in the left-hand side. The pen has a glass capillary tube from the reservoir to the tip. The tip is a piece of platinum capillary tubing.

The reservoir holds sufficient ink for at least 20 to 30 days use, depending on the kind of record that is being made. The amount of ink re-

maining in the pen is visible at all times. The ink is quick drying and can be furnished in red.

K. PRINT HAMMER MECHANISM

The print hammer which makes a single dot on the chart, can be fitted with a stylus which produces a dot inside of a circle. The large circle dot record is easier to read from a distance. If the print hammer does not strike the ribbon properly it can be bent to do so.

The print hammer carriage slides on the humidity compensating bar and is moved up and down scale by means of a split nut on a spiral shaft. Wear of the threads and backlash is taken up by a spring which keeps a slight pressure on the split nut.

When the print hammer lever rises on, then drops off a tooth on the color cam ratchet, the print hammer is released, dropping and making a mark on the chart through the colored ribbon.

L. PRINT WHEEL MECHANISM

The print wheel rotates in a plane parallel with the temperature divisions on the chart. Any inaccuracy in the indexing (which is not likely) cannot affect the accuracy of the temperature record; it will merely introduce a slight error in the time record of the character being printed.

Because the purple ink pad has a much longer life than any other color, it is used on instruments printing all records in a single color. This is felt to be a distinct advantage from the maintenance standpoint. The purple ink pad wheel is interchangeable with the multi-color ink cartridge wheel, on 2 to 12 record instruments; above 12 records only a solid color wheel can be used. It is possible to change from one to the other in the field, if desired.

Driving gears, etc. do not need to be removed, and accordingly require no retiming after changing the print wheel or the ink pad wheel.

TABLE SHOWING THE COLORS ON MULTI-COLOR PRINT WHEELS

No. of Records	Switch Point Number											
	1	2	3	4	5	6	7	8	9	10	11	12
2	GREEN	RED										
3	GREEN	RED	PURPLE									
4	GREEN	RED	PURPLE	BLUE								
5	GREEN	RED	PURPLE	BLUE	BLACK	BROWN						
8	GREEN	RED	PURPLE	BLUE	BLACK	BROWN	GREEN	RED				
12	GREEN	RED	PURPLE	BLUE	BLACK	BROWN	GREEN	RED	PURPLE	BLUE	BLACK	BROWN

M. THERMOCOUPLE BURN-OUT SAFETY FEATURE

A thermocouple burn-out safety feature can be provided on a single record controller. This feature operates as follows: when the thermocouple burns out, the galvanometer circuit is opened. The galvanometer pointer assumes a predetermined position below the normal neutral which causes the pen carriage to move upscale. When the pen passes the control point, the furnace is automatically shut down until the burned out thermocouple is replaced. A red arrow is engraved on the step table .040" below to the left of the black arrow at the center of the neutral step. The mechanical and electrical zeros are then adjusted to bring the pointer to this red arrow position. The secondary pointer, however, has not been changed and still contacts the neutral step of the step lever when the pointer is at the black arrow on the step table. The .040" distance between the middle of the neutral step and the red arrow may be either two or three steps below the neutral step, depending upon the slope of the step table.

If the thermocouple burns out, the galvanometer circuit is opened and the pointer swings to its mechanical zero position at the red arrow. This causes the secondary pointer to contact the step lever two or three steps above or away from the neutral step on the step lever, which causes the drive pawls to move the large spur gear to give the pen an upscale motion. This motion continues until the pen reaches the upper limit of its travel. In its travel, it passes the control index whereupon the control shuts off the furnace. The slidewire contact, meanwhile, has been moved with the pen, but since the galvanometer circuit is open, the position of this contact is immaterial. When a new thermocouple is connected properly, the instrument operates as usual at the black arrow balance step, which means that the electrical system is displaced .040" from its zero position. When the thermocouple burnout safety feature is used, the linear shift or pointer displacement is taken care of in calibration by adjusting the No. 8 spool. The resistance of the No. 1 spool, which is a shunt around the galvanometer, is also increased (depending upon the millivolt span) to give greater damping of the galvanometer on open circuit. This damping causes the pointer to settle down more rapidly to its mechanical zero if the thermocouple burns out so that the pen carriage can begin to move upscale at once to shut off the furnace. The No. 1 spool (see Dwg. D-2209) which without burn-out feature, is only in the circuit when the standardizing switch is moved, is now connected permanently in the circuit by a connection from the top stud of the No. 1 spool to a short stud provided for this purpose.

N. MERCURY SWITCHES

The mercury switch is a hermetically sealed glass enclosure, usually cylindrical in shape, containing a quantity of mercury, an atmosphere of hydrogen gas or a vacuum, and either two or more electrodes, or provisions for dividing the mercury into separate pools. Due to its liquid nature and electrical conductivity, the mercury will make or break an electric circuit when the switch is tilted from the horizontal position. The mercury switches are used to operate relays controlling valve action or heater loads. If the load is small enough to be handled by the mercury switch, relays are eliminated, which reduces the amount of wiring and the danger of trouble from extra contacts, and eliminates all danger of corrosion at the contacts as well as danger of explosions in the presence of explosive vapors, fumes, etc. The mercury switches can be used to operate signal lights if desired, instead of a valve.

There are certain precautions which must be observed if entirely satisfactory results are to be obtained from the mercury switches.

1. Switches must not be overloaded. Ratings given are maximum ratings and should not be exceeded.
2. Proper external leads must be used. Also, the leads to the switches should not be changed. If the leads are too small, they become overheated and this heat is transferred to the seals of the switch, resulting in damage to the tube.
3. Switches supplied by other manufacturers should not be substituted for those supplied by The Brown Instrument Company. Mercury switches are of two distinct types, "snap action" and "slow action". It is most important that snap action switches be used where there is a definite snap on and off action. They must not be used for slow acting applications such as thermostats. Switches marked slow action or not marked, may, in general, be used on either type of action.
4. Note that the ratings given in the specifications for each switch are for heater, or non-inductive loads. These ratings do not apply to inductive loads, such as coil, or motor loads. Such a load has a high rush current and a high kick-back current when the circuit is broken. For this reason, the inductive load which any particular mercury switch will handle is considerably smaller than its heater or resistance load rating. Ratings are given in the Mercury Switch Specifications Table on the following page.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1358

Page No. 18

MERCURY SWITCH SPECIFICATIONS

ITEM NUMBER	PART NUMBER		SWITCH RATING A-C OR D-C AMPERES NON-INDUCTIVE LOAD		DESCRIPTION	LENGTH OF LEADS
	BROWN	M-H	125V	250V		
1	15533	H-169-3	25	20	On-off, 2 electrodes, Mercury to Mercury Contact	16
2	15653	C-465-12	10	5	On-off, 2 horizontal electrodes at one end, Mercury to Metal Contact	24
3	15748	C-640-2	5*	3*	3-position 5 electrodes, 1 Mercury to Metal Contact in each position.	20
4	17126	C-636-2	5*	3*	3-position 4 electrodes, Mercury to Metal Contacts no contacts on neutral.	18
5	74793	H-172-2	45	35	On-off, 2 electrodes, Mercury to Mercury Contact	12

Rating for a-c only. On d-c the rating is 3 amps. @ 125 Volts or 1.5 amps. @ 250 Volts (non-inductive load).

The above ratings are the capacity of the mercury switches only and are listed for purposes of identifying the mercury switches. These will differ from the nameplate rating. This is due to the limitations of the control cables which are rated at 5 and 25 amps. However, it is possible to combine cables of any capacity, such as combining two 25 amp cables for up to 50 amps. In any case the limiting capacity of the control circuit of any instrument is always the rating stamped on the instrument nameplate.

SECTION 1359
Issue 2

Section 1359
Page No. 1
of 12 Pages

MECHANICAL ADJUSTMENTS AND
CORRECTIVE DATA

The Brown Type 113 Potentiometer Pyrometer
and Resistance Thermometer

This section covers the mechanical adjustments and corrective data which, when followed, will make servicing of these instruments easier.

- A. PEN
- B. PRINT WHEEL MECHANISM
- C. PRINT HAMMER
- D. THERMOCOUPLE SWITCHES
- E. CHART FEED ADJUSTMENT
- F. HUMIDITY COMPENSATOR ADJUSTMENT
- G. CHECKING THE CALIBRATION (Mechanical Adjustments)
- H. TIME CYCLE ADJUSTOR
- I. STEP LEVER ADJUSTMENT
- J. GALVANOMETER ADJUSTMENTS
- K. PAWL SELECTOR LEVER
- L. VIBRATION OF KIDNEY CAM
- M. REPLACING MOTOR CAPACITORS
- N. SLIDEWIRE

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1359

Page No. 2

A. PEN

If the pen is replaced on a single record instrument the instrument should be checked for mechanical calibration.

Proceed as follows: Run the pen upscale, if the pen point does not stay on the last chart line bend the left-hand end of the pen holder either forward or backward until the pen point is in register with the upper chart line.

To start the ink flowing tilt the pen point downward 45°, at the same time work pen cleaning wire in capillary to wet capillary tube which will assist the ink in flowing to the point. Withdraw the wire slowly.

If there are air bubbles trapped in the glass capillary, the pen will cease to write. When this occurs, place finger over the filling hole and hold in palm of hand or in warm water until the ink starts to flow.

If there is dirt in the capillary, the ink will not flow. In such cases, wash pen out in clean, warm water.

B. PRINT WHEEL MECHANISM

1. Ink Pads

When the printed characters on the chart become faint, the inkpad (or pads) requires re-inking, reversing, or replacing.

- a. Re-inking: Apply ink (of proper color) to the pad, at the rate of a drop or two at a time, until the pad cannot absorb more ink. Use the applicator supplied with the bottle of ink. Remove excess ink with a blotter. On multi-colored instruments, care must be used so that excess ink on one pad will not run over to the adjacent pad.

NOTE: All 16-record instruments and single color printing recorders require PURPLE INK.

- b. Reversing: If ink pad becomes worn it may be reversed in position so that the end formerly under the metal cap of the ink wheel assembly is exposed for making contact with the numeral wheel.

Refer to Fig. 1359-1. Unscrew the thumb nut and remove the complete ink pad wheel from the instrument. The metal cap can then be slipped off, exposing the felt ink pads. Remove each pad (or the one pad for single

color instruments) and replace it in the same slot with its position reversed, so that a new surface is under the printing characters. Slip the metal cap over the ends of the pads and the moulded form. Replace the assembly onto the print wheel carriage of recorder insuring that the knob on the moulding enters the slot on the gear assembly. Replace the thumb nut and tighten firmly by hand.

- c. Replacing: When both ends of a pad become worn it is necessary to replace them with new pads. The replacement is done in same manner as "Reversing" except that new pads are inserted.

2. Print Wheel Adjustment

After some months of service, the print wheel may need a minor adjustment to insure printing of full characters. Need for adjustment is indicated by the printing of the top or bottom of the character, thus +^o or +_z instead of +2.

To correct this condition, stop the instrument and proceed as follows, referring to Figure 1359-1.

- a. If upper part only, of numeral is being printed, loosen set screw B and tighten set screw A on the spur gear and hub assembly.

Rotate the printing cam and ratchet assembly on the right-hand side plate until a numeral is printed. If sufficient adjustment has not been made, repeat until printing is correct.

- b. If lower part only, of numeral is being printed, loosen set screw A and tighten set screw B on the spur gear and hub assembly.

- c. Rotate the printing cam and ratchet assembly until a numeral is printed. If sufficient adjustment has not been made, repeat until printing is correct.

NOTE: Make sure that both set screws A and B are tight when the final adjustment is made.

C. PRINT HAMMER

1. Print Hammer Adjustment

The print hammer, which makes a single dot on the chart can be fitted with a stylus which produces a dot inside of a circle. The large circle being easier to read from a distance.

INK PAD WHEEL

THUMB NUT

SET SCREW A

SET SCREW B

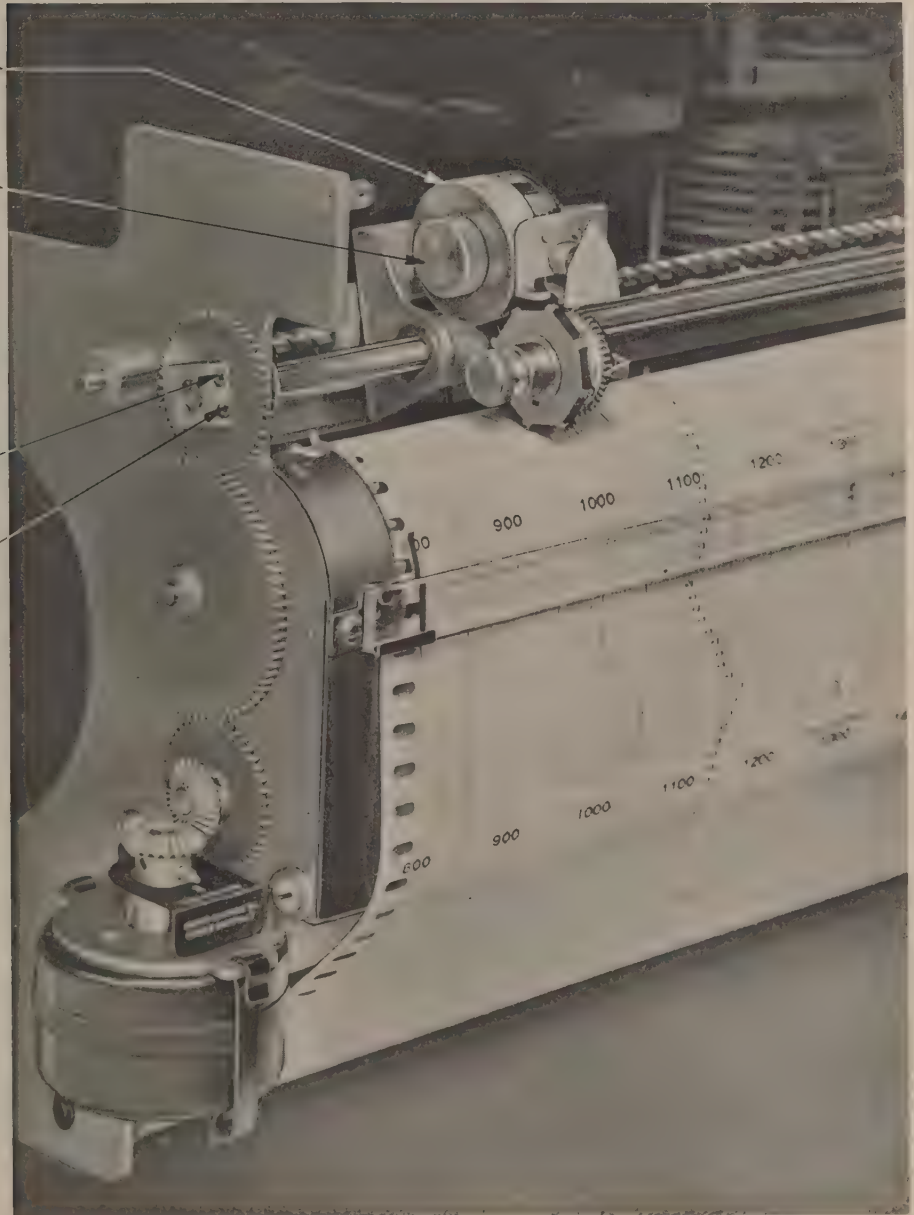


Figure 1359-1
Left-Hand Side Plate of
Print Wheel Instrument

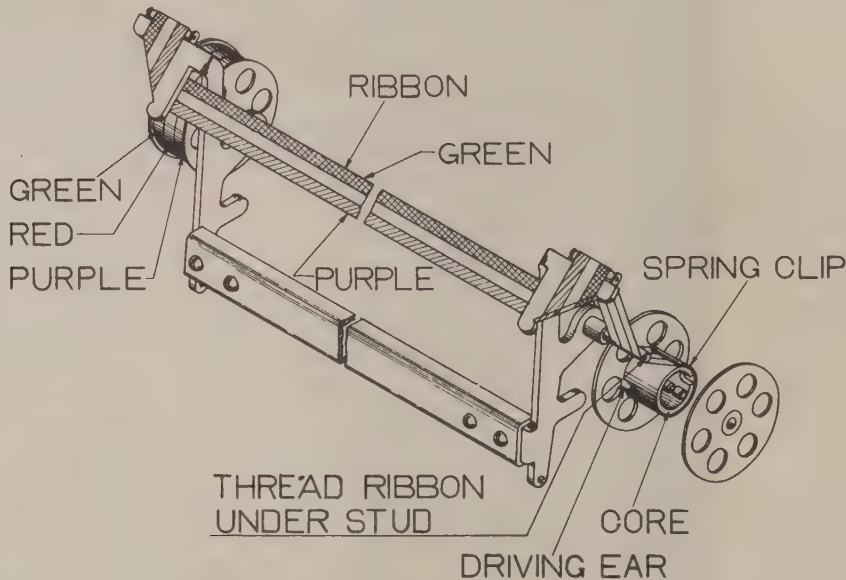
If the print hammer does not strike the ribbon properly it can be bent to do so.

2. Replacing Multi-Colored Ribbon

The multi-colored ribbon reroll is driven from the chart drum through a spur gear. The ribbon is rerolled in direct proportion to the speed of the chart roll; that is, the ribbon will run out about one day after the entire chart has run through. The ribbon should be renewed at the same time the chart is renewed.

driving gear engages into the slot in the core. Then snap the guide disc onto the right-hand ribbon stud. The slack in the ribbon can now be taken up by turning the left-hand ribbon spool by hand until the ribbon is tight.

The supply ribbon reel has been provided with a friction spring which applies the proper friction to prevent the ribbon from curling. It is very important that the ribbon be renewed after having been run through once.



Drawing 16-G-15
Ribbon Assembly on Print Hammer Potentiometer

Charts and ribbons should be ordered in equal quantities for multiple recorders. For the ribbon specify part number 15270.

To renew the ribbon, remove outer ribbon guide discs which are held in place by snap action. Remove the used ribbon from the right-hand side, and retain only the empty core and clip. The new ribbon must be placed on the left-hand ribbon stud, purple side first; then snap the left-hand guide disc into place. Attach the used core to the end of the ribbon by means of the spring clip shipped with the new ribbon.

Wind up about a turn clockwise, thread the ribbon over the ribbon carrier and under the stud as shown in Drawing 16-G-15, and slip the core on the right-hand ribbon stud with the purple side next to the instrument, making sure that the

D. THERMOCOUPLE SWITCHES

1. Oil Switch Adjustment on Print Wheel Instruments

If, for any reason, it becomes necessary to remove the entire oil switch assembly or replace any of the parts in the printing or switching mechanism, it will be necessary to set the switch in correct relation to the print wheel so that thermocouple number 1 is connected at the time figure 1 is printed.

To make this adjustment, stop the instrument, refer to Figure 1359-2 and proceed as follows:

- a. See that the printing cam and ratchet assembly, and the geneva gear are in locked position.
- b. Remove cotter from the spur gear and remove the gear.

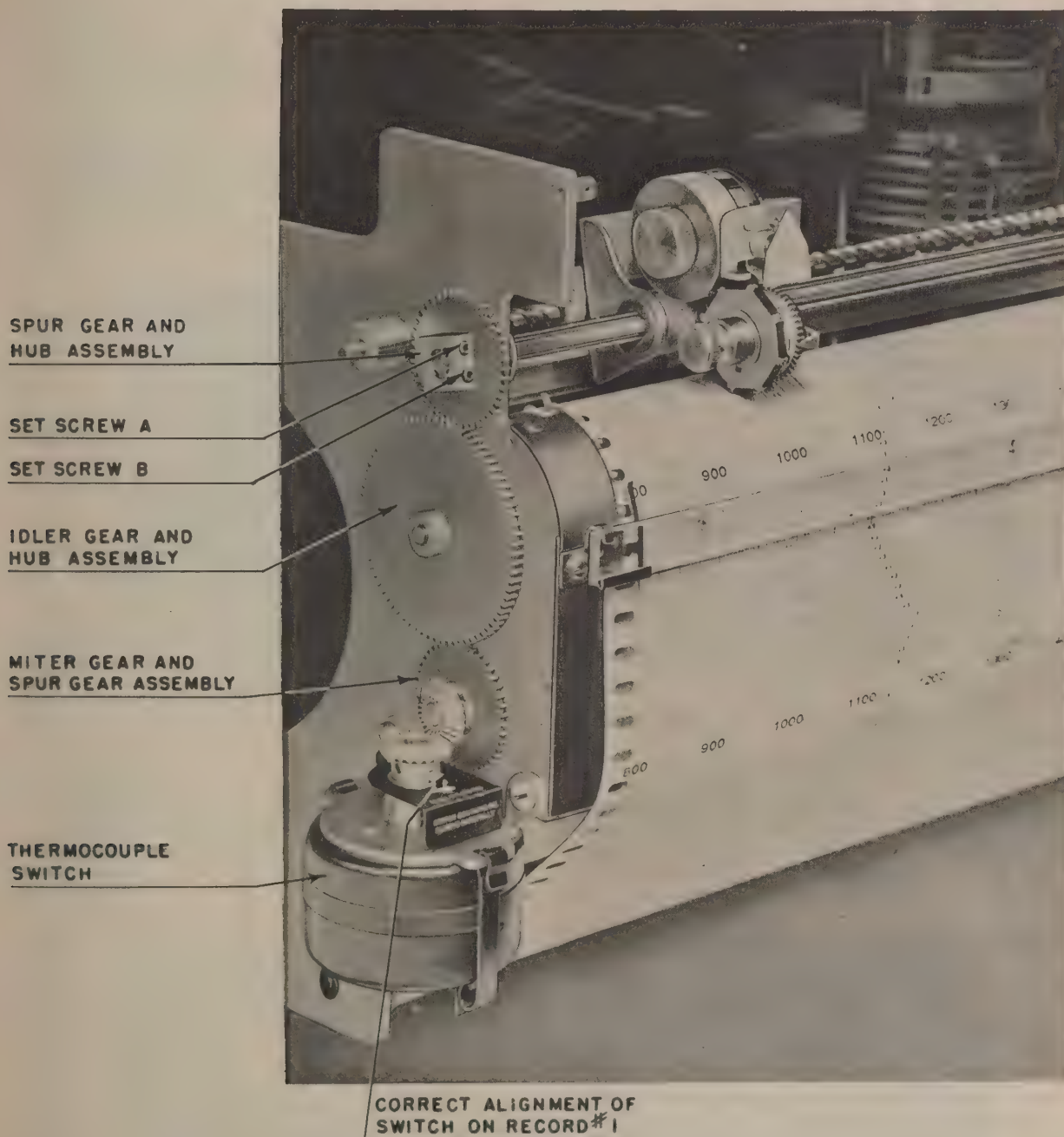


Figure 1359-2
Thermocouple Selector Switch and Printing
Mechanism - Left-Hand Side Plate of
Print Wheel Instrument

- c. Loosen the set screws in the mitre gear and spur gear assembly and rotate the gear on the oil switch assembly until the small projecting pointer on the vertical shaft of the oil switch is in alignment with the mark on the top of the switch, labeled No. 1 Record. Refer to Figure 1359-2.
- d. Tighten the set screws in the mitre gear and spur gear assembly.
- e. See that set screws A and B in the spur gear and hub assembly are tight and flush with the side of the square hub (in their mid-position).
- f. Rotate the spur gear until the numeral 1 on the record indicating wheel is directly under the index on the front of the print wheel carriage assembly.
- g. Replace the idler gear and cotter being sure not to move the spur gear any more than necessary.
- h. Rotate the printing cam and ratchet assembly until a numeral is printed. If the entire numeral is not printed correctly adjust the print wheel as described in this section under paragraph entitled, "Print wheel Mechanism".

2. Oil Switch Adjustment on Print Hammer Type Instrument

If for any reason it becomes necessary to remove the oil switch or replace any of the parts on the switching mechanism, it will be necessary to set the thermocouple switch in connection relation with the Print Hammer.

To make this adjustment refer to Drawing 16-G-13 and proceed as follows:

- a. With the pointer on the indicating dial pointer to record #1, set the thermocouple switch brushes as shown in Drawing 16-G-13 with the brushes farthest away from the shaft on the left side (looking into the bottom of the switch) and line up the right side of the brush mounting screw with the left side of the shaft and the left side of the notch in the cover.

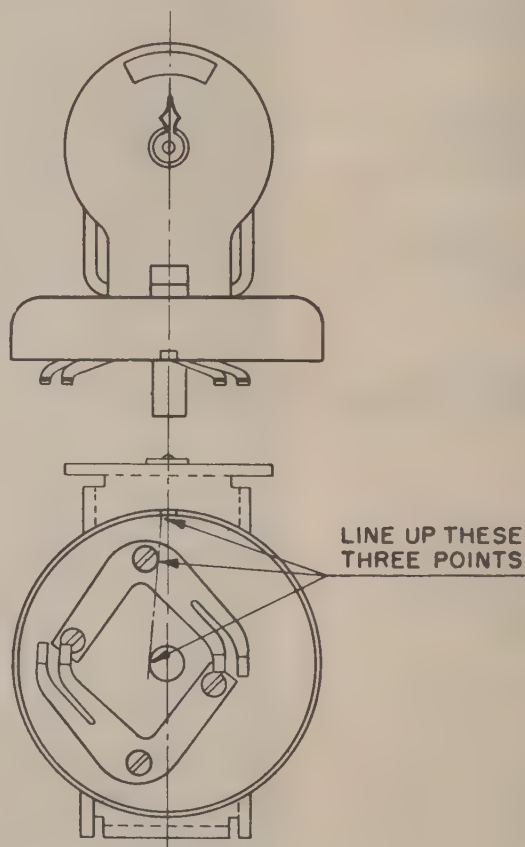
Tighten the set screws to prevent a change in this relationship.

- b. Mount the switch making sure that the print hammer has just printed a green dot and the pointer is on record #1 on the dial.

3. Brush Adjustment

If the brushes have been accidentally bent adjust for proper tension as follows:

Adjust the brush tips to a distance (approximately $.15/64"$) away from the brush holder so that a force of approximately 125 grams will deflect the brushes until the distance between the bottom edge of the switch case and the bottom of the brushes is $5/32"$.



Drawing 16-G-13

Print Hammer
Brass Contact Type
Thermocouple Switch

E. CHART FEED ADJUSTMENT

Figure 1359-3 shows the adjustable 6-step chart speed arm which governs the number of teeth taken on each stroke of the table cam lever. The speed of the chart can be varied readily by loosening the clamping screw and revolving the step cam until the desired chart speed figure falls underneath the operating lever. The numbers on the cam indicate inches of chart speed per hour. The standard chart speed is 2 inches per hour.

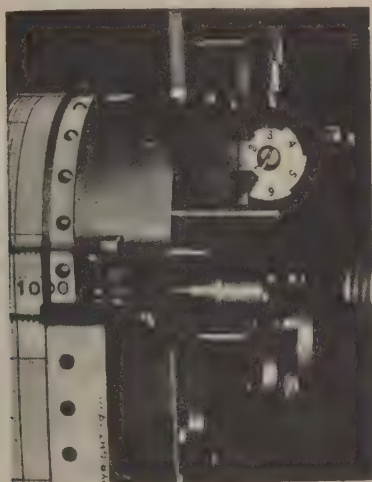


Figure 1359-3
Chart Speed Cam

If the chart speed is not correct check the frequency of the motor or the action of the latching pawl on the ratchet. A one tooth movement of the ratchet will give a 1 inch per hour chart speed.

F. HUMIDITY COMPENSATOR ADJUSTMENT

In case of excessively rough handling the humidity compensator strip may be torn. This can be readily observed by noting that the pen or print hammer is far out of register with the index on the scale. Also, in making an effort to adjust the humidity compensator by means of the screw, reached through the small hole to the right of the chart, shown in Figure 1359-3, there will be no response. To replace the strip, remove the writing platen by removing the two lower screws (one of these is shown in Figure 1359-3) on the chart clips at the tear-off glass. Remove the cotter at each end of the compensator strip shown in Figure 1359-4 and lift off the paper clamps. After inserting the new compensator strip, replace the paper clamps, attaching them to the paper so that the clamp on the left end is in the center of the elongated hole. The replacement strip can temporarily be a strip of chart cut to the correct width. This should be considered as a temporary measure only. Complete compensator strips with clamps attached are assembled and accurately adjusted at the factory and should be used for best results. Attach the clamps on the studs, the left one first, and replace the cotters. Fasten the writing platen back in position, then adjust the pen position by means of the eccentric screw adjustment.

The location of the eccentric adjusting screw is shown in Figure 1359-4. This adjustment is made when the pen carriage is at the extreme lower end of the scale and the drive gear stops are in contact. The pen or print hammer is then set to register with the lowest line of the chart by turning the adjusting screw.

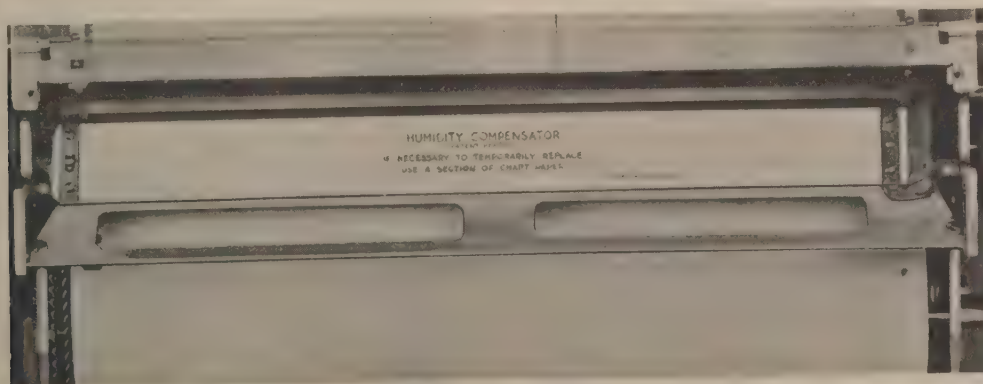


Figure 1359-4
Humidity Compensator Strip

G. CHECKING THE CALIBRATION (MECHANICAL ADJUSTERS)

When the full scale position has been reached, as determined by the gear stops, the pen should register full scale reading on the chart. The pen carriage index should register full scale reading on its scale; the slidewire contact should be at the upper end of its travel, but not striking the clamp on the slidewire winding, and the arrows on the two bevel gears should be in register. If the pen is out of register see that the pen is properly located in the pen holder and hung properly on the carriage. If this does not bring the pen to the correct position, loosen the two set screws attaching the small spur gear to the spiral shaft; turn the spiral shaft by hand to bring the pen to the proper position and tighten the set screws, being sure that the gear stops are engaged and the spiral shaft has no endplay, although still free to turn. Then, if the pen carriage index is out of register, loosen the screws holding the scale; slide the scale into register and retighten the screws. Before attempting any adjustment of the bevel gears or the slidewire contact, run the pen to the opposite end of the scale and see that the slidewire contact is at the lower end of its travel, but not striking the lower clamp. If the arrows on the spur gears are in register, loosen the two set screws in the hub of the large spur gear and rotate the bevel gear so that after tightening the set screws the upper and lower limits of travel of the slidewire contact will be equidistant from the clamps at the ends of the slidewire. Now, run the pen carriage to the extreme low position to see if the pen, or print hammer, stops exactly on the lowest line on the chart. If the index is correct and the pen or print hammer off, adjust the humidity compensator, as described in this section under paragraph entitled, "Adjusting the Humidity Compensator".

H. TIME CYCLE ADJUSTER

Only the Print Hammer Potentiometer has this adjuster. By the use of the small adjustable numbered cam (shown in Figure 1359-5), the maximum printing cycle of the instrument can be set from six to twenty strokes. The advantage of this feature on a multi-point controller where the controlled temperatures are reasonably close together is obvious, as only a few strokes are required to reach the balanced position and pass over to the next point. This is valuable where time is an important factor in obtaining close control.

If the instrument prints before it comes to balance, check for friction or dirt between the balanced and unbalanced sectors.

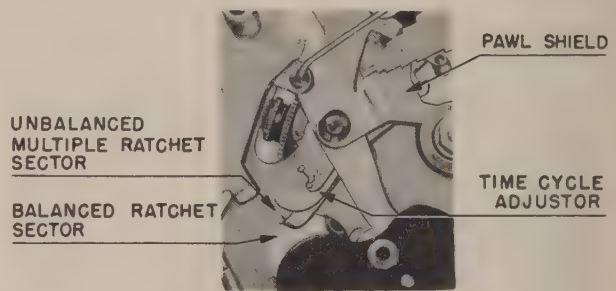


Figure 1359-5
Time Cycle Adjustor

1. STEP LEVER ADJUSTMENT1. Step Adjustment

After an instrument has been in service for a long time, wear or lost motion might occur between the various moving parts so that when the galvanometer pointer contacts the first step away from the neutral step on the step table and is attempting to come to a balanced position, the motion, in being transmitted from the step table to the spur gear, is not sufficient to move the spur gear through the small distance corresponding to one tooth. In this case, to correct, it is only necessary to take a few light file cuts on the first step off neutral of the main step lever so that it will move farther before being stopped by contacting the secondary pointer. The pawls will then move farther giving the spur gear the necessary one-tooth movement. This will tend to balance the galvanometer deflection by giving the slidewire a new point of contact.

2. Bearing Adjustment

An adjustment is supplied on the step lever as a means of providing the necessary clearance between the pawl selector lever and the secondary pointer. This adjustment is used, if the secondary pointer is prevented by the pawl selector lever from reaching its highest position.

The adjustment is made as follows:

Hold the galvanometer pointer all the way over to the left and then run the kidney cam around until the lowest step on the step galvanometer step table contacts the galvanometer pointer. At this point in the cycle the secondary pointer should be in its highest position. If it contacts the pawl selector lever before reaching its highest position loosen the hex nut and turn the eccentric stud (holding the ball bearing cam follower on the step lever) in either direction until the secondary pointer is free to move into its highest position. Adjust to allow a slight clearance in this position then tighten the hex nut on the eccentric stud and recheck as above. If necessary repeat the adjustment.

J. GALVANOMETER ADJUSTMENT

If the galvanometer pointer rests against either the upper edge or the lower edge of the clamping bar, take off the back cover plate of the galvanometer to see if either suspension is broken. If so, stop the motor when the galvanometer clamping table is in the down position and not contacting the pointer. Then remove the two leads, turn the hold-down clip in a counter-clockwise direction until the clip clears its studs and remove the galvanometer assembly.

After removing the galvanometer unit from the instrument, it should be placed upon a flat surface. The suspension tension is relieved by turning the marked adjusting screws in the back. The broken suspension tips can be readily removed after loosening the small screws in the coil and mounting sockets. The new suspension tips should be carefully inserted to their full depth, using tweezers. Then clamp the tips with the small screws. Care must be taken to see that the suspension ribbon is lying flat and that both zero adjusting arms are in mid-position.

After the suspension is clamped in place, it is drawn tight by turning the adjusting screws two or three turns in the direction indicated by the arrow in the bakelite moulding. This adjustment is not critical. Now hold the galvanometer frame in an upright position. Adjust the bottom zero adjusting arm until the pointer is at right angles to the back of the moulded frame. The galvanometer coil should then be balanced to overcome any effect resulting from the instrument not being mounted in an absolutely horizontal position.

With the suspensions under tension, place the bakelite frame in a horizontal position, lying on its side. If the pointer is not in balance in this position, hold the coil lightly against the cylindrical core and turn the counter-weight on the counterpoise screw. The weight should be screwed out if the pointer falls, and vice-versa. When a balanced condition is obtained, the weight should be about $1/16$ " from the end of the counterpoise. If a balance can not be obtained because the weight is not heavy enough, turn the bakelite frame on its back, hold the coil in the V notches and push down on the saddle straps (C-D or E-F in Figure 1359-6) with a pair of tweezers until a balance is obtained. This operation bends the suspension tip sockets forward. The sockets are mounted on soft copper saddles so that they can be readily bent.

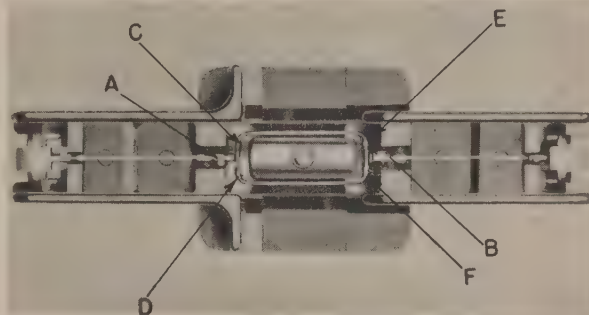


Figure 1359-6
Position of Galvanometer for
Replacing Suspensions

The bakelite frame should now be turned over on its back, and the condition of balance noted. If the pointer does not come to a vertical position, but deflects either to one side or the other, adjustments should be made by slightly bending one of the suspension tip sockets (A or B in Figure 1359-6) in the same direction as the pointer deflects. This should be done without releasing the tension. These two tests should be repeated until the system is balanced in both positions. The galvanometer pointer should be approximately in the zero position so that the final adjustment to bring it to zero can be made by means of the zero adjuster. An additional adjustment for zero balance is provided at the bottom end of the galvanometer.

The spring clip to which the top suspension is fastened extends back and upward to contact the gear in the galvanometer cover, which is moved by the zero adjuster screw. Before the cover is replaced, this spring clip should be bent forward to insure having a good contact with the gear.

If the galvanometer pointer sticks to the upper clamping bar, it is caused by the stripper not coming down low enough to free the pointer. To remedy, clean the pointer tip and clamping bar with Carbona or carbon tetrachloride, and bend the ear on the upper right side of the step table downward so that it will bring the stripper bar about 0.025 inch below the clamping bar.

If the step table does not contact with the galvanometer, remove the galvanometer cover and see that the step table rises freely until it contacts the galvanometer pointer. See that the step table is free in its bearings, as any binding at this point would cause a jumping action.

Inspect the phosphor bronze springs which lift the table and see that they are under proper tension. The tension from these springs should

be sufficient to cause the step table to rise at a steady rate. A jerky action of the step table will result in excessive wear of the galvanometer pointer.

If the step table slips off the galvanometer pointer, proceed as follows:

1. Clean galvanometer pointer and steps.
2. If excessive vibration is present, mount the instrument on vibration absorbers.
3. Eliminate all vibration due to misalignment of the step lever or rough cam.
4. Make sure the step table is mounted straight.
5. Make sure the galvanometer pointer is installed with the raised edge left by the blanking die, toward the step table.
6. If step table and galvanometer pointer edges have been worn round they should be replaced. When either of these parts need replacing always replace both the step table and pointer.

K. PAWL SELECTOR LEVER

1. Spring Adjustment

If the pen or print carriage does not move in response to galvanometer deflections, wipe off the faces of the driving pawls. They may be oily. **This is very important.** If this does not correct the trouble, see if the leaf spring on the pawl selector lever causes alternate pawls to be thrown into engagement with the large spur gear when the secondary pointer is moved one step each side of neutral. The instrument should respond properly every time. If it fails to respond, the leaf spring is not set properly. An easy way to make this adjustment is to move the secondary pointer one step off neutral from either side and adjust the drive pawl spring by bending it lightly until it follows the pawl to the end of its travel. It is usually better to remove the large spur gear in making this adjustment. If the main step lever assembly, at the bottom of its stroke, touches the drive pawl spring, correct this condition by giving the main step lever assembly a slight bend, or twist in toward the side plate.

2. Lever Adjustment

It might happen that the very edge of the selector lever tooth contacts with the secondary pointer and vibration might cause the pointer to slip

off the edge of this tooth and fall down to the next lower tooth. To correct for this, it is only necessary to make a slight adjustment on the knurled screw on the end of the secondary pointer positioning lever. Turning this knurled screw clockwise will move the secondary pointer down.

L. VIBRATION OF THE KIDNEY CAM

Excessive back-lash in the drive mechanism may be detected by observing the action of the large kidney-shaped cam on the right-hand side plate. This cam should rotate at a uniform angular velocity and should not show any jumping action under the influence of the spring driven step lever. If back-lash is observed, it may be caused by a loosening of the set screw on the flexible shaft, or the motor itself may have developed excessive back-lash in its reduction gearing. The effect of back-lash in the motion of the kidney cam will tend to cause excessive wear on the secondary pointer. Ordinarily, the step lever descends smoothly until one of its steps contacts with the secondary pointer, but in the presence of excessive back-lash there is a sudden impact as the step lever jumps downward. Such a condition should be corrected immediately.

M. REPLACING MOTOR CAPACITORS

1. General

Either the capacitor and/or motor can be replaced.

2. Replacing Motor and Capacitor

- a. Turn off power supply.
- b. Disconnect the motor lead wires, loosen the flexible shaft clamp and remove the motor from the chassis.
- c. If not already there, drill and tap two 10-32 holes in the under surface of the chassis as shown on sketch 16-G-14.
- d. Install the new motor on the chassis, connect the lead wires and tighten the flexible shaft clamp.
- e. Unfasten the capacitor from the motor by removing the 2 mounting screws. **Do not disturb the capacitor connections.** Fasten the capacitor to the under surface of the instrument chassis with two 10-32, 1/4" machine screws.
- f. Test the motor by turning on the power.

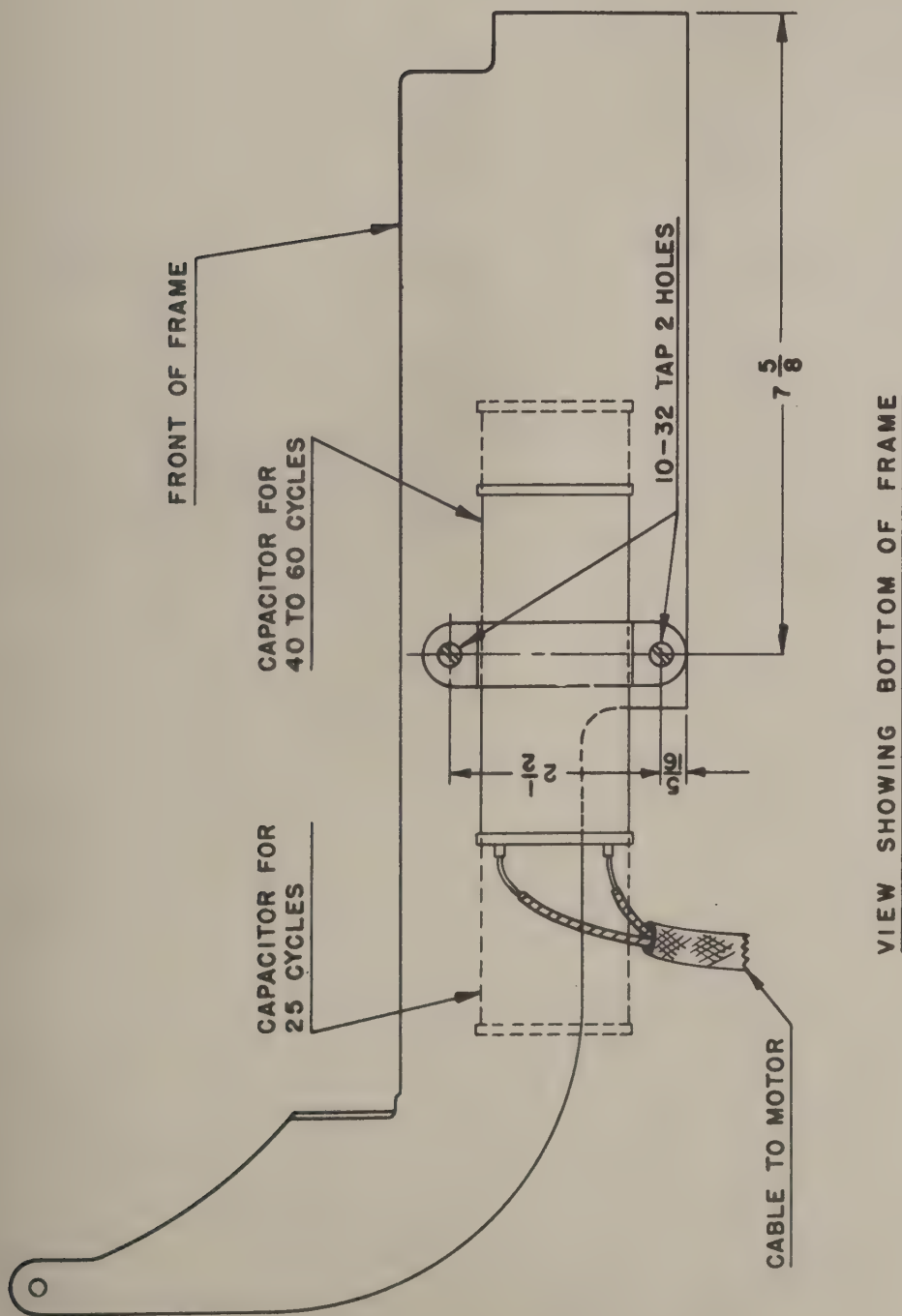


FIG. 16-G-14

METHOD FOR MOUNTING NEW TYPE MOTOR CAPACITOR
FOR STRIP CHART POTENTIOMETERS

3. Replacing Capacitor Only

- a. Turn off power supply.
- b. Disconnect the lead wires from the capacitor at the terminal lugs and remove old capacitor from motor frame.
- c. If not already there, drill and tap two 10-32 holes in the under surface of the chassis as shown on sketch 79-S-32.
- d. Fasten the new capacitor to the under surface of the chassis with two 10-32, 1/4" machine screws.
- e. If the existing leads are too short for the new capacitor location, it will be necessary to splice them to a short length of two conductor #18 B & S gauge, braided covered lamp cord. Solder the joints and apply a layer of rubber, then friction tape the splices in the approved Underwriter's manner. The lead length for a 25 cycle motor should be 9 inches. It should be 11 inches for a 60 cycle motor.

f. Solder the ends of the wires to the capacitor terminal lugs.

g. After soldering, paint the terminals with green insulating cement, Brown Part #75692. **Make certain all live parts are completely covered with cement.** Allow the first coat to dry for 26 minutes and apply a second coat.

h. Test the motor by turning on the power.

N. SLIDEWIRE

The glass jar when it is being replaced should be centered around the slidewire, before the wire bail is fastened. The bail is fastened in position by means of the clamp on the bottom, which applies a force against the bottom of the glass jar. Care should be taken to avoid placing the bail too far toward the back of the jar as the fitting on the right-hand end of the flexible shaft may strike against the bail clip. To remedy this condition, move the glass jar forward so that this can not occur.

ELECTRICAL ADJUSTMENTS AND CORRECTIVE DATA ON
THE BROWN TYPE 113 MECHANICAL POTENTIOMETER AND RESISTANCE THERMOMETER

This section covers the Electrical adjustment and corrective data which when followed will make servicing these instruments easier.

- A. MEASURING CIRCUIT OF POTENTIOMETER
PYROMETER
- B. MEASURING CIRCUIT OF RESISTANCE THER-
MOMETER
- C. CHANGING THE RANGE
- D. CHECKING CALIBRATION (Mechanical Adjust-
ments)
- E. CHECKING CALIBRATION OF POTENTIOMETER
PYROMETER (Electrical Adjustment)
- F. CHECKING CALIBRATION OF BALANCED WHEAT-
STONE BRIDGE RESISTANCE THERMOMETER
(Electrical Adjustments)
- G. GALVANOMETER SENSITIVITY ADJUSTMENT
- H. SET THE MECHANICAL ZERO
- I. STANDARDIZE THE BATTERY CURRENT

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1360

Page No. 2

A. MEASURING CIRCUIT OF POTENTIOMETER PYROMETER

If the galvanometer pointer deflects to the left, and it is impossible to bring it to the zero or balanced position with the standard cell balancing switch in the "BAL" position and the rheostat set in either the maximum or minimum position, the battery may require renewal or there may be a poor connection in the battery circuit. See that the battery binding posts are tight. If this does not correct the trouble, install a new battery. Another possibility is that the battery polarity may have been reversed. See that the nine screws at the rear of the slidewire unit are tight.

If the galvanometer is stable, and the instrument draws a straight line without any deviation, the external circuit may have a very high resistance, or may be open.

If the galvanometer pointer swings erratically with the balancing switch in the "RUN" position, it is an indication that there is:

1. A high resistance or break in the thermocouple circuit.
2. The thermocouple may be burned out.

Check the thermocouple circuit and make sure that all connections are tight. Check the connections at the galvanometer binding posts. If this does not correct the trouble, clean the standard cell balancing switch.

To clean the switch, remove the two screws holding the switch cover in place and rub the contact surfaces with a piece of cloth. Coat with vaseline and replace the cover.

When the galvanometer deflects hard to either side with the standard cell balancing switch in the "RUN" position, it is an indication that the temperature of the couple is above or below the temperature range of the instrument, or that the couple or leads have been short-circuited or reversed.

If the record is scattered:

1. Inspect the thermocouple circuit for loose connections.
2. Possibly the thermocouple is badly deteriorated and has introduced a very high external resistance.

3. Check for excessive vibration which can usually be noted when the galvanometer pointer fails to come to rest before it is clamped. The effect of the vibration can usually be corrected by adjusting the tension on the galvanometer suspensions. In extreme cases, mount the instrument on a vibration absorbing mounting.

4. The slidewire may need cleaning. Proceed as indicated under section entitled, "Maintenance".
5. In multiple type instruments, it may be necessary to clean the multiple switch. To clean proceed as indicated under section entitled, "Maintenance".

B. MEASURING CIRCUIT OF RESISTANCE THERMOMETER

NOTE: Do not use Magneto to detect bulb or instrument failure. Use dry cell and buzzer.

If the instrument fails to operate: (Draw a straight line - recorder; or galvanometer does not deflect when scale is rotated - indicators),

1. Battery circuit may be open. Check the battery connections and battery leads.
2. The "C" leads to the bulb may be open. Check the circuit, if the "C" lead on one bulb connected to a multiple recorder is open, the instrument will fail to record the temperature of that particular bulb.
3. The key switch may not be depressed - indicators.

If a record is produced, but the pen moves up-scale on a decrease in temperature at the bulb, and vice versa, the battery connections are reversed. Check the polarity of the connection and reverse, if necessary.

If the instrument produces a record at the lower edge of the chart - recorders; or tries to balance at a point below the lower end of the scale - indicators:

1. The bulb may be at a temperature lower than the minimum range of the instrument.
2. If the temperature at the bulb is known to be within the range of the instrument.

- a. The lead from the "B" terminal to the bulb may be open, or the "A" & "B" or "A" & "C" leads may be reversed. Check the connections against the circuit diagrams.
- b. A portion of the bulb winding may be short circuited. Replace the bulb with one known to be in good condition.
- c. There may be a short circuit between the leads from the bulb to the "A" & "B", or the "A" & "C" terminals. Locate and clear the short circuit.

If the instrument produces a record at the upper edge of the chart - recorders; or tries to balance at a point above the upper end of the scale - indicators:

1. The bulb may be at a temperature higher than the maximum range of the chart.
2. If the temperature of the bulb is known to be within the range of the instrument, the lead from "A" terminal to the bulb may be open, or the bulb may be open-circuited. Check the circuit through both.

If a recorder produces a record line which consists of a number of pronounced steps, or an indicator fails to give sufficient response to variations in dial setting the sensitivity is too low.

1. If the cells are new, check the connections and number required in case more than two are needed. The cells may be incorrectly connected together, or too few cells may have been installed.
2. If the cells have been installed for some time, they have probably become exhausted. Renew the cells.

If a recorder produces a record which oscillates back and forth, never reaching a balance, even though the temperature is reasonably constant, or if on an indicator, the galvanometer pointer moves too far for small changes in dial setting, the sensitivity is too high. If the cells have just been installed or replaced, too many have been used. Check the number of cells required.

If the record is scattered:

1. Inspect the bulb circuit for loose connections.

2. Possibly the bulb is badly deteriorated and has introduced a very high external resistance.
3. Check for excessive vibration, which can usually be noted when the galvanometer pointer fails to come to rest before it is clamped. The effect of vibration can usually be corrected by adjusting the tension on the galvanometer suspensions. In extreme cases, mount the instrument on a vibration absorbing mounting.
4. The slidewire may need cleaning. Proceed as indicated under section entitled, "Maintenance".
5. In multiple type instruments, it may be necessary to clean the multiple switch. To clean switch proceed as indicated under section entitled, "Maintenance".

C. CHANGING THE RANGE

First, stop the motor in a position so that the driving pawls are not engaged. Then turn the main driving gear so as to bring the pen and slidewire contact to the full scale stop position. This will bring the arrows on the large bevel gears together. Then loosen the nine small screws in the terminal block on the back of the slidewire unit and by removing the two screws on the top of the slidewire assembly the entire unit can be lifted out. In placing the new slide assembly into the instrument, first turn the bevel gear on the slidewire assembly so that the slidewire contact reaches its upper stop position, and with the pen in its full scale stop position, place the new slidewire in position with the arrows on the two bevel gears together, replace and tighten the screws. For best operation use fresh oil in new slidewire.

Now change the chart and scale, loosening the scale mounting screws, and lift up. If the change of range parts includes a new galvanometer table step, change this by springing the old table out and installing the new one. This is done most readily with the table in its highest position. If a new galvanometer is supplied, this must also be changed. On Potentiometer Pyrometers, change the cold junction compensation spool, which is mounted on the terminal plate and marked "C.J.". See section entitled, "Description of and Data on Component Parts of Type 113 Mechanical Potentiometer", for correct C.J. spool, galvanometer, and step table.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1360

Page No. 4

D. CHECKING THE CALIBRATION (MECHANICAL ADJUSTMENTS)

When the full scale position has been reached, as determined by the gear stops, the pen should register full scale reading on the chart. The pen carriage index should register full scale reading on its scale; the slidewire contact should be at the upper end of its travel, but not striking the clamp on the slidewire winding, and the arrows on the two bevel gears should be in register.

If the pen is out of register see that the pen is properly located in the pen holder and hung properly on the carriage. If this does not bring the pen to the correct position, loosen the two set screws attaching the small spur gear to the spiral shaft; turn the spiral shaft by hand to bring the pen to the proper position and tighten the set screws, being sure that the gear stops are engaged and the spiral shaft has no end play, although still free to turn. Then, if the pen carriage index is out of register, loosen the screws holding the scale; slide the scale into register and retighten the screws.

Before attempting any adjustment of the bevel gears or the slidewire contact, run the pen to the opposite end of the scale and see that the slidewire contact is at the lower end of its travel, but not striking the lower clamp. If the arrows on the spur gears are in register loosen the two set screws in the hub of the large spur gear and rotate the bevel gear so that after tightening the set screws the upper and lower limits of travel of the slidewire contact will be equi-distant from the clamps at the ends of the slidewire. Now, run the pen carriage to the extreme low position to see if the pen, or print hammer, stops exactly on the lowest line on the chart. If the index is correct and the pen or print hammer off, adjust the humidity compensator, as described in section entitled, "Mechanical Adjustments and Corrective Data".

E. CHECKING CALIBRATION OF POTENTIOMETER PYROMETER (ELECTRICAL ADJUSTMENTS, INSTRUMENTS WITH CHECKING TERMINALS)

Potentiometer pyrometers furnished with checking terminals can be checked easily from the front of the instrument. This greatly simplifies the procedure, especially when the instrument is mounted flush on a panel board with conduit connections.

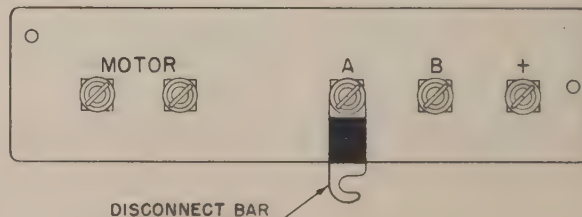
IMPORTANT: The terminal block and cold junction compensating resistor on this instrument are so designed that the temperature will be equalized between each pair of extension lead terminals and the resistor. In order to permit the checking thermometer to assume the correct cold junction temperature, leave it in place at least fifteen (15) minutes before taking a reading.

This is especially important if the thermometer is at a temperature considerably different from the cold junction temperature at the time it is inserted.

Where it is necessary to check a number of instruments, the use of several thermometers will permit their insertion for a long enough time to avoid delaying the work, while they are assuming the correct temperature.

To check the instrument, proceed as follows:

1. Open the instrument door.
2. Place a mercury-in-glass pocket thermometer in back of the terminal plate (either lay the thermometer on the cable or fasten with tape).
3. Loosen binding posts marked A and B, located on the motor lead terminal plate. Allow red connecting bar to hang loose.
4. Connect a low resistance portable potentiometer of known accuracy (Brown Model 126W3V) to terminals B and + shown in Dwg. 16-G-16.



Drawing 16-G-16
Checking Terminal Plate

5. Set the mechanical zeros and standardize the battery currents of both instruments.
6. Read the cold junction temperature on the thermometer. Determine the millivolt equivalent of the temperature at which it is desired to check the instrument and set the "Millivolt" knob and dial of the portable instrument to this value.
7. Set the key switch on the portable potentiometer to the "Zero" position.
8. Allow the instrument to balance.
2. Loosen binding posts marked A and B, located on the motor lead terminal plate. Allow red connecting bar to hang loose.
3. Connect a laboratory type resistance box of known accuracy to terminals 8 and 4 of Fig. 16-G-16. This resistance box should be provided with settings to 0.1 ohm.
4. Set the mechanical zero of the instrument.

EXAMPLE: A calibration check is desired at 1450°F on a potentiometer calibrated 0 - 2000°F M.A. thermocouple. The cold junction temperature is 70°F. From the M.A. temperature-millivolt table based on 32°F cold junction, we find that 1450°F = 32.80 millivolts and 70°F = 0.84 millivolts. The setting of the portable instrument should be the difference between the two values, 32.80 - 0.84 = 31.96 millivolts.

If it is desired to measure the emf of the thermocouple, connect the portable potentiometer to terminals A and + shown in Dwg. 16-G-16.

The cold junction temperature is read, as before, from the thermometer inserted into the hole provided for it.

On multiple record instruments it is necessary to stop the instrument when the thermocouple switch is connected to the desired thermocouple as shown by the record indicating wheel.

NOTE: Always replace the red connecting bar and tighten the three binding posts A, B, and + when checking is completed.

F. CHECKING CALIBRATION OF BALANCED WHEATSTONE BRIDGE RESISTANCE THERMOMETERS (ELECTRICAL ADJUSTMENTS, INSTRUMENTS WITH CHECKING TERMINALS)

Balanced Wheatstone Bridge Resistance Thermometers furnished with checking terminals, can be checked easily from the front of the instrument. This greatly simplifies the procedure, especially when the instrument is mounted flush on a panel board with conduit connections.

To check the instrument, proceed as follows:

1. Open the instrument door.

5. From the table of temperature-resistance equivalents for the Brown resistance thermometer bulb, determine the equivalents of the temperature at which it is desired to check the instrument, and set the resistance box to this value.
6. Allow the instrument to balance.

If the resistance of the leads to each bulb is known, it is possible to measure the resistance of the bulb by proceeding as follows:

1. Connect a Wheatstone bridge of known accuracy to terminals A and + of Fig. 16-G-16
2. Measure the resistance of the bulb, including two leads, and then reverse the connections at the terminals of the Wheatstone bridge and take a second reading. Call the first reading X and the second Y. The meaning of these two readings is equal to the resistance of the bulb plus two leads to the bulb.

Bulb resistance = $\frac{X + Y}{2}$ - Resistance of two leads to bulb

3. The temperature of the bulb corresponding to its resistance is given in the table referred to above.
4. On multiple record instruments it is necessary to stop the instrument when the bulb switch is connected to the desired bulb as shown by the record indicating wheel.

NOTE: Always replace the red connecting bar and tighten the three binding posts, A, B, and + when checking is completed.

G. GALVANOMETER SENSITIVITY ADJUSTMENT

When leaving the factory, the sensitivity is adjusted for average conditions of external resistance and vibration. When an adjustable galvanometer sensitivity resistor is supplied and if installation conditions differ from this average, adjust the sensitivity as follows:

The sensitivity adjustment should be made to provide maximum sensitivity without overshooting. If the instrument overshoots when coming into balance, the galvanometer is oversensitive and the terminal B should be moved clockwise around the adjustable resistor, Fig. 1360-1. If the instrument requires a large number of steps to get into balance, the galvanometer is undersensitive and the terminal B should be moved counter-clockwise around the adjustable resistor. In relocating movable terminal B, loosen the small set screw with a jeweler's

screw driver and retighten it securely on the new terminal. Care should be taken to see that terminals are not short circuited by being bent together.

H. SET THE MECHANICAL ZERO

While the motor is running, push the switch lever on the slidewire unit to its center "ZERO" position, and turn the zero adjusting screw on the front of the galvanometer cover so that the step of the galvanometer step table indicated by the small **BLACK** arrow contacts the galvanometer pointer.

I. STANDARDIZE THE BATTERY CURRENT

Push the switch lever to the extreme left "BAL" position with one finger, and turn the knurled disc above it with the thumb until the step of the galvanometer step table indicated by the **BLACK** arrow contacts the pointer. This should be done daily.

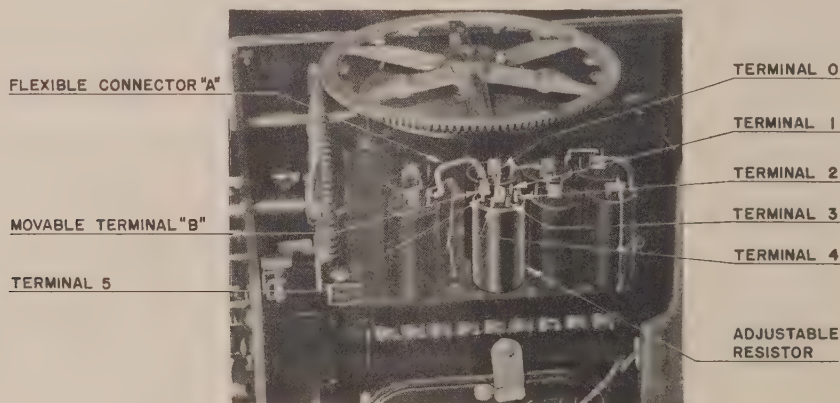


Figure 1360-1
Adjustable Galvanometer Sensitivity Resistor

Reference Drawings

10-G-56

10-G-73

SECTION 1361

Issue 2

Section 1361

Page No. 1

of 15 Pages

CONTROL ADJUSTMENTS AND CORRECTIVE DATA
FOR THE BROWN TYPE 113 POTENTIOMETER PYROMETER
AND RESISTANCE THERMOMETER

This section covers the control adjustments and corrective data which when followed will make servicing these instruments easier.

- A. SETTING THE CONTROL INDEX
- B. MERCURY SWITCH CONTROL ADJUSTMENTS
- C. CHANGING THE THROTTLING RANGE OF A PROPORTIONING TYPE POTENTIOMETER
- D. ADJUSTING THE M-H TYPE RELAY
- E. ADJUSTING THE RELATROL RELAY SENSITIVITY
- F. M-H PROPORTIONING CONTROL
- G. THE BECK CONTROL MECHANISMS
- H. THE A.T.C. RELATROL AND BALANCER CONTROL SYSTEMS
- I. AIR-O-LINE CONTROL ADJUSTMENTS
- J. FULL THROTTLER CONTROL ADJUSTMENTS
- K. THE PROGRAM CONTROL SYSTEM ADJUSTMENTS
- L. THE AUXILIARY SWITCH
- M. THE INTERRUPTER SWITCH

A. SETTING THE CONTROL INDEX

The control index is set by pressing in and turning the small knob immediately above the door knob on the front of the instrument. Turning this knob in a counter-clockwise direction moves the index upscale.

CAUTION: Do not attempt to set the control carriage while the control bar (which is the flat bar behind the scale) is in the DOWN position.

The control setting may be locked by removing the control setting knob. This can be done by releasing the small screw on the control knob shaft bushing, inside the door.

The maximum control setting on a control instrument using mercury switches is $3/4$ " below the full scale pen position.

The maximum control index setting on an instrument with proportioning control is $1-5/8$ " below the full scale position. The index cannot be raised above this value due to limitations in the construction of the instrument.

1. Controlling at One Temperature (Single or Multiple Record Instruments)

The control index is set by the knurled knob directly above the door knob as described above.

2. Controlling at Two Different Temperatures (Multiple Record Instruments)

An instrument of this type has two control carriages which may be linked together and set as a unit by turning the control setting knob directly above the door knob, or may be set independently. The right-hand control carriage is always set by means of the control setting knob and the two carriages are connected by a slotted link.

If the indices are to be maintained in fixed relationship to each other, loosen the thumbscrew which locks the control carriages together. This screw is located on the left-hand carriage, in the slot of the connecting link. Slide the left-hand carriage, until the desired distance between the indices is obtained, then tighten the thumbscrew. The setting knob may now be used for setting the indices at the desired point on the scale.

When it is unnecessary to maintain a fixed relationship between the indices the external setting knob may be used to position both indices

if the thumbscrew in the connecting link is loosened (but not removed). The lower index should be moved by turning the knob and allowing the right-hand control carriage to pull or push the left-hand carriage to the desired point after which the right-hand carriage may be positioned.

If the desired distance between the indices is greater than the length of the slot in the connecting link, the link must be removed from the instrument and the left-hand control carriage must be set separately by grasping with the fingers and sliding to the proper point.

CAUTION: Do not attempt to move the control carriage to a new position by grasping the control index as the index may become bent so that it will no longer indicate the true control point.

Either control carriage may be fastened at any position on the scale by tightening the corresponding thumbscrew which appears above the scale near the index.

B. MERCURY SWITCH CONTROL ADJUSTMENTS

On 3-position control instruments, see that the adjustable neutral step on the control table has the proper width for the desired operating condition. The width of this neutral may be changed by loosening the two screws in the control table (reached through the two holes in top) and moving the adjustable step to the desired width. This adjustment permits a widening of the neutral step up to approximately $1/2$ ".

If the mercury switch fails to open or close the circuit, inspect the glass tube to see whether it has been broken or cracked. A crack in the glass tube will result in a smoky appearance and the switch should be replaced. On the curved type mercury switch, improper action is sometimes caused by not having the instrument mounted in a level position.

If the switch selections appear to be erratic check the switch assembly. Make sure the switch shaft does not turn and that the individual switches have sufficient friction on the hubs to hold them in whatever position they are placed.

Each mercury switch supporting clip is provided with a friction washer to hold the switch in whatever position it may be pushed by the control fingers. Check the friction on these cup washers and make sure that it is sufficient to hold the switch after it has been tilted by the control mechanism.

C. CHANGING THE THROTTLING RANGE OF A PROPORTIONING TYPE POTENTIOMETER

The Brown Potentiometer has an accessible and easily adjustable method of changing the throttling range. Refer to Dwg. 10-G-56. If adjustment is necessary, open the instrument case and swing the frame forward. The stud of the connecting link will be found to be in the extreme outer hole of the movable contact actuating lever. Moving the link to one of the three inner holes increases the angular motion of the movable contact and thus narrows the throttling range.

It is recommended that the link be moved inward, one hole at a time, only after a trial run seems to indicate that the narrower throttling range might be used without causing a cycling of the controlled variable. The effect of changing the throttling range is illustrated in Dwg. 10-G-73.

D. ADJUSTING THE M-H TYPE RELAY

Adjust the pilot relay contact gaps to .010" total, and those for the load relay to .050" total. The gap should be equally divided on either side of the contact blade with no power on the relay.

After the above procedure, connect the relay to the power line, motor, and instrument so that the operation can be tested.

The load relay contact should always snap to approximately its center position without sticking to either side on breaks, should not buzz or arc continuously when making contact on either side, and should not chatter excessively.

If the load relay contacts buzz or chatter excessively, check to make certain that the pilot relay contacts are clean.

If the valve motor hunts, even though the load relay operates correctly as described above, the relay may be too sensitive. This condition may be corrected by unscrewing one or the other of the pilot relay contacts a quarter of a turn at a time until the hunting stops. Usually a one-half turn wider setting of the pilot relay contact gaps will be sufficient to prevent hunting.

E. ADJUSTING THE A.T.C. RELATROL RELAY SENSITIVITY

The degree of accuracy with which a control system will maintain a variable at a given control point depends upon the ability of the system to respond to minor deviations of the variable. This response, in turn, is dependent to a great extent upon the sensitivity of the proportioning relay.

A knob and dial (labeled "Relay Sensitivity"), with arbitrary calibration from zero to 10, are located in the Relatrol Relay and provide a means of adjustment so that the maximum sensitivity, consistent with stable operation, may be attained.

The initial setting of this knob should be at zero on the dial.

After the system has been energized and before the control adjustments are made, the proper relay sensitivity should be determined. Stop the instrument motor in a position to permit free movement of the galvanometer pointer by manually turning the large gear on the right-hand sideplate. Turn the "Relay Sensitivity" knob slowly toward 10 until a rapid cycling condition develops, then return the knob toward zero 1/2 division, or until the cycling stops.

A faint continuous clicking noise from the bridge relay indicates a cycling condition and will be evident when the sensitivity has been increased beyond the critical point. This clicking noise is caused by oscillation of the bridge relay armatures between its two extreme positions.

If the location selected for the Relatrol Relay is subject to considerable extraneous noise, the presence of a cycling condition can be detected by the use of two test lamps. Connect one test lamp between terminals V_2 and 4B, and the other between V_2 and 5B.

The condition of these lamps will indicate now the conditions existing within the control system. When the motor is being operated in the direction to close the valve, the lamp connected between terminals V_2 and 4B will be energized. Conversely when the motor is being operated in the direction to open the valve, the lamp connected between terminals V_2 and 5B will light. When the system is in balance both lamps will be out.

Oversensitivity of the Relatrol Relay is indicated by a rapid alternate flashing of the two lights intermittently, as the bridge relay armature oscillates. Turn the "Relay Sensitivity" knob toward zero until the intermittent flashing of the lights ceases.

Remove the test lamps from the relay terminal plate.

F. M-H PROPORTIONING CONTROL

1. With M-H Relay

In making adjustments to the control system it is important that ample time be allowed for the final effect to be observed and evaluated.

a. Adjustment of Throttling Range

Throttling range is the span through which the controlled variable must pass in order to cause full travel of the motor, and is expressed as a percentage of the total span of the controlling instrument.

As shipped, Brown Potentiometers for use with M-H Proportioning control, are adjusted for a throttling range of approximately 6%.

This setting has been found satisfactory for the majority of applications and should not be changed unless control results indicate the necessity.

If it is desirable to change the throttling range proceed as outlined in part entitled, "Changing the Throttling Range of a Proportioning Type Potentiometer", in this section.

b. Setting Angular Rotation of Motor

By means of limit switches, the angular rotation of the crank shaft is adjustable through any part of its 180 degree revolution. The angular rotation should not be decreased more than necessary.

CAUTION: Under no circumstances should the angular rotation be limited to less than 60°. With any shorter travel, the sensitivity of response of the motor is decreased.

To adjust the limit switches remove the section of the motor housing directly opposite the crank shaft, loosen the knurled sleeve, set the limit switch handles to the desired positions, and lock in place by tightening the knurled sleeve.

The limit switches should be set at approximately equal distances from their end positions so that the operating range will be at the center of the resistance element in the motor. This will permit use of the full throttling range for which the controller is set.

2. With Relatrol Relay**a. Energizing the Control System**

Place the instrument motor toggle switch in the **ON** position, then close the line switch to the control circuit. Place the toggle switch marked **LINE** in the Relatrol Relay in the **ON** position and place the switch marked **Hand-Auto** in the **Auto** position.

The Proportioning Motor will assume a position as determined by the instrument pen or pointer with respect to the control index.

b. Adjusting Throttling Range

As shipped, Brown Potentiometers for use with M-H Proportioning Control, are adjusted for a throttling range of approximately 6%. This setting has been found satisfactory for the majority of applications and should not be changed unless control results indicate the necessity.

The Relatrol Relay has a knob and dial marked "Throttling Range". This knob should be turned to "10" on the dial when the system is placed in operation. If it is found necessary to decrease the throttling range, the knob should be turned toward "0". As the throttling range adjustment is moved from "10" to zero the effective throttling range is reduced 35%. Thus the throttling range may be varied from 6% to 3.9%.

In the event that further reduction of the throttling range is desirable, the Brown Potentiometer has an accessible and easily adjustable method. For further changing the throttling range refer to part entitled, "Changing the Throttling Range of the Proportioning Type Potentiometer", in this section.

By properly combining the two methods, the throttling range may be set at any value between 6% and 1.9%.

The effect of changing the throttling range is illustrated in Dwg. 10-G-73.

c. Adjusting Manual Reset

The knob and dial, marked "Load Compensation", on the Relatrol Relay permits the operator to manually reset the position of the valve with respect to the pen or pointer of the instrument and, thus, to compensate for variations in the operating conditions of the furnace, such as an increased or decreased load.

Set the knob at "0" on the dial. Allow the system to operate a sufficient length of time for the temperature to reach a balanced condition. If the temperature is below the control index, turn the knob toward **OPEN** to increase the valve opening with respect to the pen position. If the temperature is above, turn the knob toward **CLOSE** to decrease the valve opening with respect to the pointer position.

It is recommended that the knob be moved in small steps in order that the effect of the change in valve position in relation to pen position may be observed before making a new adjustment.

d. Setting Angular Rotation of Motor

This set is as outlined under part entitled, "M-H Proportioning Control with M-H Relay", in this section.

e. Operating Manually

To control the valve position manually place the **Hand-Auto** switch in the **Hand** position. Pressing the **OPEN** switch will cause the valve to move toward the fully-open position; pressing the **CLOSE** switch will cause the valve to move toward the fully-closed position.

G. THE BECK CONTROL MECHANISM

1. Adjustments of Beck Single Function Control System with M-H Relay

In making adjustments to the control system it is important that ample time be allowed for the final effect to be observed and evaluated.

a. Adjustment of Throttling Range

As shipped, Brown Potentiometers for use with the Beck Mechanism, are adjusted for a throttling range of approximately 10.5%. This setting has been found satisfactory for the majority of applications and should not be changed unless control results indicate the necessity. To change the throttling range, proceed as outlined in part entitled, "Changing the Throttling Range of the Proportioning Type Potentiometer."

2. Adjustments of the Beck Single Function Control Mechanism with Relatrol Relay

a. Energizing the Control System

Place the instrument motor toggle switch in the **ON** position; then close the line switch to the control circuit. Place the toggle switch marked **LINE** in the **Relatrol** Relay in the **ON** position and place the switch marked **Hand-Auto** in the **Auto** position. The Beck Mechanism will assume a position as determined by the instrument pen or pointer with respect to the control index.

b. Adjusting the Relay Sensitivity

To adjust the relay sensitivity, proceed as outlined in part entitled, "Adjusting the A.T.C. Relatrol Relay", in this section.

c. Adjusting Throttling Range

As shipped, Brown Potentiometers for use with Beck Single Function Control are adjusted for a throttling range of approximately 10.5%. This setting has been found satisfactory for the majority of applications and should not be changed unless control results indicate the necessity. If an adjustment is necessary, proceed as outlined in the part entitled, "M-H Proportioning Control with Relatrol Relay", in this section.

d. Adjusting Manual Reset

The knob and dial, marked "Load Compensation", on the Relatrol Relay permit the operator to manually reset the position of the valve with respect to the pen or pointer of the instrument and, thus, to compensate for variations in the operating conditions of the furnace, such as an increased or decreased load. If necessary to adjust, see instructions for adjusting manual reset under part entitled, "M-H Proportioning Control with Relatrol Relay", in this section.

e. Manual Operation

To control the valve position manually place the **Hand-Auto** switch in the **Hand** position. Pressing the **OPEN** switch will cause the valve to move toward the fully-open position; pressing the **CLOSE** switch will cause the valve to move toward the fully-closed position.

3. Adjustment of the Beck Triple Function Control Mechanism with M-H or Relatrol Relay

The triple function control mechanism has the following additional control adjustments:

a. Adjusting Proportionate Reset

Adjustment of proportionate reset, referred to as C-2 action in the Beck Triple Function Control System, is made manually by turning the knurled knob at the motor end of the Beck Mechanism.

This reset knob is graduated from zero to 70% and the setting is identified by the graduation which coincides with the white line on the mechanism housing. The % mark is omitted in the graduations.

The recommended initial setting of the knob is 40%.

A comparison of the control record and the curves entitled "Proportionate Reset" on Dwg. 10-G-73 will indicate whether this initial setting must be increased or decreased to produce stable control to a definite temperature.

b. Adjusting Timed Reset

The interrupting contact, which periodically connects the C-3 rheostat across the motor resistor, is located on the right-hand side-plate of the instrument. The operation is factory adjusted to a 2-1/2 second period of contact in a one minute cycle and should not be changed.

The C-3 rheostat is located on the back of the instrument chassis and may be exposed to view by swinging the chassis out of the case.

An initial adjustment of "6" is recommended. Further adjustment is seldom required. However, after the system has been in operation for a time, a comparison of the control record and the curves entitled "Timed Reset" in Dwg. 10-G-73 may indicate that the initial setting should be changed.

c. Effect of Control Adjustments

The effects of control adjustment shown in the sample curves on Dwg. 10-G-73 will vary for different furnaces; principally in regard to the time cycle of the oscillation. Deviations caused by load changes must not be confused with oscillations caused by over-correction of the fuel rates. The deviations caused by load changes are more likely to develop at irregular intervals, while over-correction of the fuel rates will cause more uniform cycles of oscillation.

(1) Throttling range

This has been covered in the part entitled, "Changing the Throttling Range of a Proportioning Potentiometer", in this section.

The effect of changing the throttling range is illustrated in Dwg. 10-G-73.

(2) Proportionate reset

Proportionate reset, or C-2 action, is a permanent displacement of valve position with respect to open position, required

to return the controlled variable to or near the control point after a change in load demand. It is a function of the magnitude of the deviation from the control point and is expressed as a percentage of the initial valve displacement resulting from each change in load demand.

The percentage of reset established for the C-2 action is fixed to agree with the constants of the process being controlled. After the initial adjustments have been made, the reset action is entirely automatic, controlling any load within the capacity of the furnace to the set control point.

Refer to Dwg. 10-G-73 for examples of the effect upon the control record of proper and improper settings of the C-2 knob.

(3) Timed reset

Timed reset (C-3 action) is the permanent displacement in valve position, in addition to Proportionate Reset, required to return the controlled variable to the control point after a change in load demand. It is a function of the duration and magnitude of the deviation from the control point and is expressed in arbitrary units from 1 to 10.

Timed reset action is produced by a combination of C-2 action and a shunt, periodically applied, across the motor slide-wire.

C-3 shunting action has no effect when the system is in a balanced state with the temperature at the control point. However, when the system is in balance at some point other than the control point and still within the throttling range, the periodic application of the shunt will momentarily unbalance the system and cause the motor to re-position the valve slightly in a direction to force the temperature toward the control point.

This corrective action is dependent upon the value of resistance in the shunt (C-3) circuit, and the amount of deviation from the control point. As the C-3 rheostat is turned from "1" toward "10" the displacement in valve position due to C-3 action increases. Thus the total displacement for a change in load demand is dependent upon the length of time required to return the temperature to the control point.

H. THE A.T.C. RELATROL AND BALANCER CONTROL SYSTEMS1. Relatrol Control

In making adjustments to the control system, it is important that ample time be allowed for the final effect to be observed and evaluated.

a. Energizing the Control System

Place the instrument motor toggle switch in the **ON** position, then close the line switch to the control circuit. Place the toggle switch marked **LINE** in the Relatrol Relay in the **ON** position and place the switch marked **Hand-Auto** in the **Auto** position. The Valve Operator will assume a position as determined by the instrument pen or pointer with respect to the control index.

b. Adjusting Throttling Range

As shipped, Brown Potentiometers for use with A.T.C. Relatrol Control are adjusted for a throttling range of approximately 10.5%. This setting has been found satisfactory for the majority of applications and should not be changed unless control results indicate the necessity.

(1) If the A.T.C. Relatrol Relay purchased does not have a knob and dial marked "Throttling Range Adjustment" proceed as outlined in the part entitled, "Changing the Throttling Range of a Proportioning Type Potentiometer", in this section; only after observation of the control record indicates that a change in throttling range might be desirable.

(2) When the Relatrol Relay has a knob and dial marked "Throttling Range Adjustment", these should be used if it is necessary to alter the effective throttling range of the instrument. If satisfactory control cannot be obtained by means of the throttling adjustment in the relay, proceed as outlined above, to move the connecting link in, one hole at a time, on the movable contact actuating lever of the instrument.

As the "Throttling Range Adjustment" in the Relatrol Relay is moved from zero to "10", the effective throttling range is reduced 40%. Thus, with the connecting link in the outer hole, the throttling range may be varied from 10.5 to 6.3% by turning the Throttling Range Adjustment in the relay from zero to "10". With the

connecting link in the second hole, the throttling range may be varied from 9.3 to 5.6%, etc.

c. Adjusting Manual Reset

The A.T.C. Relatrol Relay has a knob and dial, marked "Load Compensation", which permit the operator to manually reset the position of the valve with respect to the pen or pointer of the instrument and, thus, to compensate for variations in the operating conditions of the furnace, such as an increased or decreased load.

Set the knob to "5" on the dial. Allow the system to operate a sufficient length of time for the temperature to reach a balanced condition. If the temperature is below the control index, turn the knob toward **OPEN** to increase the valve opening with respect to the pen position. If the temperature is above, turn the knob toward **CLOSE** to decrease the valve opening with respect to the pen position.

It is recommended that the knob be moved in small steps in order that the effect of the change in valve position in relation to pen position may be observed before making a new adjustment.

d. Operating Manually

To control the valve position manually place the **Hand-Auto** switch in the **Hand** position. Pressing the **OPEN** switch will cause the valve to move toward the fully-open position; pressing the **CLOSE** switch will cause the valve to move toward the fully-closed position.

2. Balancer Control

The A.T.C. Balancer Control System has the following additional control adjustment:

a. Adjusting Rate of Load Compensation

The initial setting of the cam should be such that the "Rate of Load Compensation" contacts are open continuously.

After making any necessary adjustments to the throttling range, as described above, adjust the Rate of Load Compensation cam so that its contact duration will cause the temperature to return to the control point as rapidly as possible without overshooting after any deviation.

Increase the period of closure of contacts to cause the temperature to return to the control point more rapidly.

Decrease the period of contact closure to eliminate hunting or overshooting of the temperature.

b. Effect of Control Adjustments

The effects of control adjustment shown in the sample curves on Dwg. 10-G-73 will vary for different furnaces, principally in regard to the time cycle of the oscillation.

Deviations caused by load changes must not be confused with oscillations caused by over-correction of the fuel rates. The deviations caused by load changes are more likely to develop at irregular intervals, while over-correction of the fuel rates will cause more uniform cycles of oscillation.

(1) Throttling range

Throttling range is the span through which the controlled variable must pass in order to cause full travel of the Valve Operator and is expressed as a percentage of the total span of the controlling instrument.

The knob and dial marked "Throttling Range" in the Balancer Relay permit a reduction of approximately 40% in the effective throttling range of the instrument as the knob is turned from zero to "10". Thus the throttling range may be varied from 10.5 to 6.3%.

In addition, the Brown Potentiometer has an accessible and easily adjustable method of changing the throttling range. Refer to Dwg. 10-G-56. Moving the link to one of the three inner holes increases the angular motion of the movable contact and thus narrows the throttling range. Throttling ranges of approximately 10.5, 9.3, 7.4, and 5.5% will be obtained as the link is moved from the outer to the inner hole.

By properly combining the two methods, the throttling range may be set at any value between 10.5% and 3.3%.

The effect of changing the throttling range is illustrated in Dwg. 10-G-73.

(2) Rate of load compensation

Load compensation is the permanent displacement in valve position required to

return the controlled variable to the control point after a change in load demand. It is a function of the duration of the deviation from the control point.

Rate of Load Compensation is the rapidity with which the corrective displacement in valve position occurs and is governed by the period of closure of an intermittent contact operated by a rotating and adjustable cam.

The setting of the adjustable cam should be such that the temperature will be forced to return to the control point as rapidly as possible after a deviation due to a change in load demand. However, the process lag is a factor which limits the maximum rate of load compensation and, consequently, the maximum setting of the cam.

A cyclic variation, called hunting, of temperature around the control point occurs when the rate of load compensation is adjusted to too high a value. This condition is due to the inability of the system to respond to the corrective action at the rate it is being introduced, and may be overcome by resetting the cam for a shorter period of contact.

1. AIR-O-LINE CONTROL ADJUSTMENTS

The Brown Air-O-Line is adjusted at the factory to operate with the characteristics as outlined below. If these adjustments have been disturbed they can be corrected by following the procedure specified.

1. Maximum Valve Pressure

With an air supply of 17 lbs. the diaphragm valve pressure should increase to at least 15 lbs. when the flapper is resting firmly on the nozzle and the connection to the air valve is pressure-tight.

- a. If the diaphragm valve pressure does not build up properly, first check for leaks in the nozzle system. This includes the unions connecting the nozzle to the pilot valve and the nozzle tube connection at the pilot valve. There may be excessive leakage from the nozzle around the flapper. This can be checked by placing a finger firmly on the nozzle and if the valve pressure builds up to 15 lbs. then the flapper does not cover the nozzle properly. The flapper should then be lined up so it is perpendicular to the nozzle axis when it is against the nozzle.

- b. Clogging of the reducer in the pilot valve, (2) in Dwg. 10-G-93 will also prevent the pressure from building up. This can be checked by removing the manual control screw (37) and running a wire through the reducing tube which is 0.008" I.D. and 3/4" long.
- c. If the trouble is not found either in the nozzle system or reducing tube, an inspection of the pilot valve exhaust port adjustment should be made. To check this adjustment move the control index or disconnect link (14) so that flapper (5) fully covers nozzle (4). Loosen the lock nut on the exhaust port (7), in Dwg. 10-G-93, and turn the exhaust port in until the valve pressure reaches a maximum and starts to drop again. Then back off 1/2 turn on the exhaust port and lock it in position.

With proper adjustment of the pilot valve, removing the flapper from the nozzle or the reverse action should cause a rapid and uniform change in control valve pressure from 0 to 15 lbs. or vice versa. If it is observed that the pressure changes rapidly at the low and high pressures, but slowly at the intermediate pressures, it indicates that the exhaust port is not located close enough to the supply port.

2. Minimum Valve Pressure

The diaphragm valve pressure should drop to zero when the flapper is removed from the nozzle.

- a. If the diaphragm pressure does not drop off, first check the manual control screw (37). This must be seated tightly. If this screw is found to be tight, check for partial clogging of the nozzle or of the exhaust port in the pilot valve.
- b. If it is found that the trouble is not due to the above then the pilot valve inlet port adjustment should be checked. The probability is that baffle (6) does not seat properly on the inlet port (1). This is corrected by removing the front cover plate from the pilot valve and then unscrewing the large hexagonal cap.

CAUTION: Do not remove the hexagonal cap with the flapper on the nozzle. Always keep the nozzle uncovered when hexagonal cap is removed.

The small nut on the end of the pilot valve shaft, which also acts as a baffle for the exhaust port, should be unscrewed and the disc which covers

the inlet port (1) should be turned in so that with the flapper away from the nozzle, the disc just covers the supply port. By listening closely the point at which the inlet port is covered can be recognized. Precaution should be taken to avoid screwing the disc in too far as this will cause distortion of the disc and it will not cover the supply port properly. After the disc has been adjusted it should be locked in place with the exhaust baffle nut.

CAUTION: When replacing hexagonal cap on pilot valve always back off on the exhaust port (7) so that it will not press against the baffle when the cap is seated.

After the hexagonal cap is replaced the exhaust port (7) should be adjusted as described in part 1. "Maximum Valve Pressure", under c.

3. Throttling Range Adjustments

With the instrument pen at the control point, changing the throttling range dial should not change the diaphragm valve pressure appreciably.

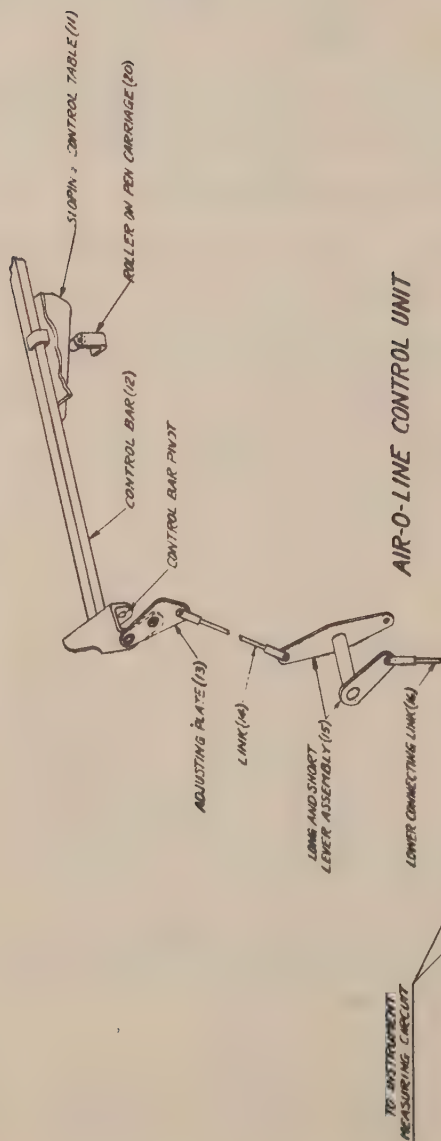
To check this action, set the control index at the real control point (this may not necessarily be at the instrument pen or pointer if the instrument adjustments have been disturbed). To find the real control point follow procedure given in 4 (a) below, but do not adjust the control point at this time. Simply find where it is and leave the index there.

With the index at the control point, observe relation between arm (26) and arm (24). These two arms should be parallel so the diaphragm valve pressure does not change when the throttling range is changed. If they are not parallel, adjust eccentric pin (27) to make them so. Whenever eccentric pin (27) is adjusted, the control point is shifted and therefore the control index must also be changed to the new control point. By adjusting eccentric pin and resetting control index alternately, the two arms (26) and (24) can be made parallel to each other when the index is at the control point. To check this adjustment operate the throttling range dial from 10% to 100% with the control index at the control point. The diaphragm valve pressure should change not more than approximately 1/4 lb. if this adjustment is made properly.

4. Adjusting Control Point

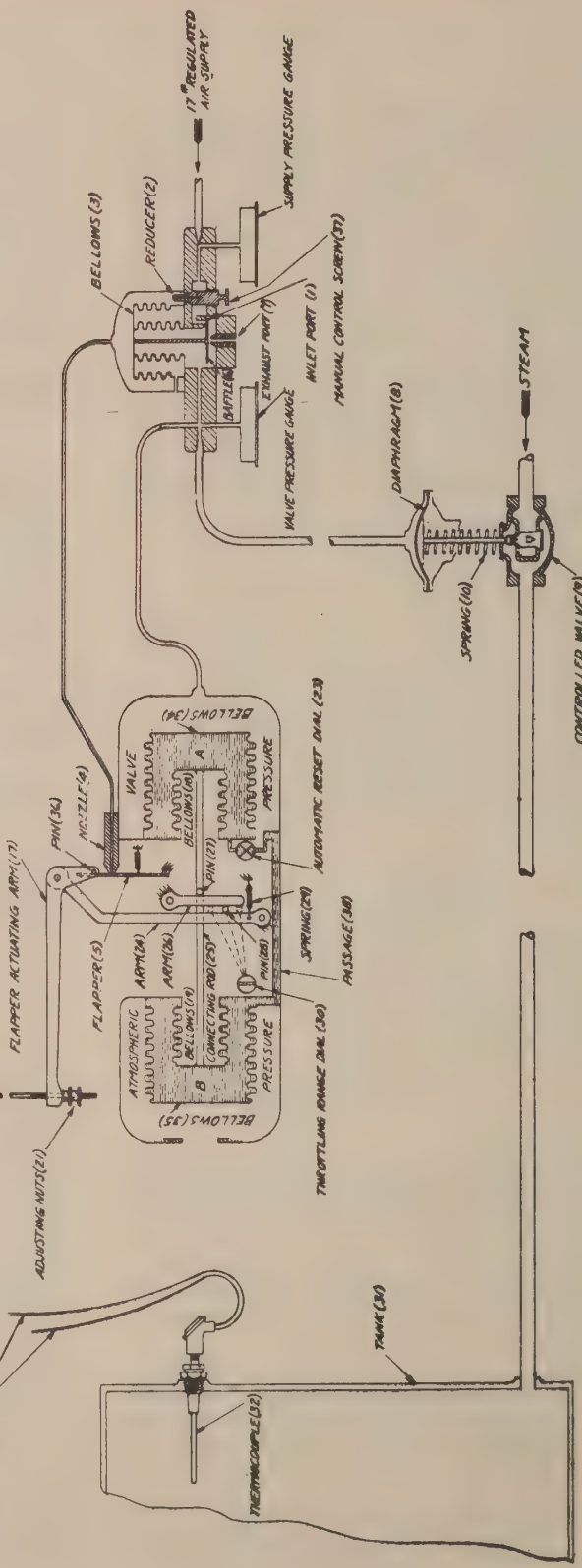
The instrument pen or pointer should coincide with the control index when the index is at the control point.

INSTRUMENT CONTROL MECHANISM



PILOT VALVE

AIR-O-LINE CONTROL UNIT



Drawing 10-G-93
Schematic Drawing - Potentiometer Air-O-Line Controller

- a. To check for control point, set the control point index to agree with the pen or pointer. Move automatic reset dial to #1 position and observe diaphragm valve pressure. If this pressure changes over a period of several minutes, then the real control point is not that indicated by the index. This check can be made more accurately with a narrow throttling range such as 10%. The real control point is the index setting at which the pressure remains steady.
- b. To adjust the index to agree with the control point, set the index to coincide with the pen or pointer and set automatic reset dial to #1 position. If the diaphragm valve pressure is observed to be falling, adjust nozzle towards the flapper; if the pressure is rising, adjust nozzle away from the flapper.

With the correct nozzle adjustment there will be no change in diaphragm valve pressure with the index coinciding with the pen or pointer and the automatic reset dial at #1.

J. FULL THROTTLE CONTROL ADJUSTMENTS

The Brown Full Throttler is adjusted at the factory to operate with the characteristics as outlined below. If these adjustments have been disturbed they can be corrected by following the procedure specified:

1. Maximum Valve Pressure

With an air supply of 17 lbs. the diaphragm valve pressure should increase to at least 15 lbs. when the flapper is resting firmly on the nozzle and the connection of the air valve is pressure tight. If the diaphragm valve pressure does not build up properly, proceed as outlined under part entitled, "Air-O-Line Control Adjustments", in this section.

2. Minimum Valve Pressure

The diaphragm valve pressure should drop to zero when the flapper is removed from the nozzle. If the diaphragm pressure does not drop off, proceed as outlined under part entitled, "Air-O-Line Control Adjustments", in this section.

3. Nozzle Adjustment

With the control index coinciding with the instrument pen or pointer and the manual reset screw in approximately its middle position, the diaphragm valve pressure should be between 5 and 10 lbs. This pressure also should not vary more than about a pound when the throttling range dial is adjusted from 10% to 100%.

If the diaphragm valve pressure does not act in this manner, it indicates that the nozzle is out of adjustment. The nozzle can be adjusted by following the procedure outlined as follows:

- a. Set throttling range dial at 10 and observe valve pressure. If it is above 10 lbs., adjust nozzle away from flapper; if it is below 5 lbs., adjust nozzle towards flapper.
- b. Move throttling range dial to 100 and repeat adjustments outlined in (a).
- c. Repeat these adjustments alternately at 10 and 100 on throttling range dial, until the pressure is within the 5 to 10 lb. range and does not change more than one pound when the throttling range dial is moved from 10 to 100.

4. Throttling Range

If the record appears to drift without any definite signs of being controlled, the throttling range dial should be moved to a smaller number. If on the other hand a periodic cycle is produced on the record, then the throttling range should be widened by moving the throttling range dial to a larger number. With proper adjustment on the throttling range dial the record will just be beyond the point of cycling.

5. Manual Reset

After the proper throttling range has been found, the control index can be made to coincide with the real control point (the point at which the instrument record is maintained), by shifting the manual reset screw. This is done by first observing the pressure on the diaphragm valve gauge (left-hand gauge), and then moving the index to agree with the instrument reading. Then adjust the manual reset screw so that pressure on the diaphragm valve gauge returns to the value observed before moving the index.

6. Manual Control

The manual control screw (37) is for use only in emergencies when it is desired to by-pass the control instrument.

Before operating this screw, first move the control index as far as possible in the direction which will drop the diaphragm valve pressure. Then turn the manual control screw in a counter-clockwise direction slowly until the desired diaphragm valve pressure is reached. These two operations should be done simultaneously where a temporary drop in valve pressure is not desirable.

INSTRUCTIONS FOR USERS OF BROWN INSTRUMENTS AND ACCESSORIES

Section 1361

Page No. 12

of 15 Pages

To return to automatic control turn the manual control screw clockwise until it is seated tightly.

CAUTION: The manual control screw must be seated tightly in clockwise direction for proper automatic operation of the instrument.

7. Corrective Data

When a full throttlor is properly adjusted for automatic control of a process, no further adjustments should be necessary. If the instrument begins to control poorly, after having been previously adjusted properly, do not tamper with the adjustments until external factors, more likely to cause trouble, have been investigated. Checks should be made of the diaphragm valve operation or for leaks in the lines connecting the instrument to diaphragm valve, air filter, and pressure regulator, any of which may contribute to poor control.

A maintenance of a clean and dry air supply to the instrument is absolutely necessary for continuous satisfactory operation. Although the instrument contains a secondary filter it is up to the primary filter to clean the air and remove liquids. Where liquids (oil and water) are excessive, the petcock at the bottom of the filter should be left partially open in order to provide a continuous drain. The filtering material in the filter should be replaced periodically, the frequency depending on local conditions.

If the diaphragm valve pressure does not build up properly and there are no leaks in the air lines, the reducer may be clogged. The reducer is a part of the manual control screw and can be removed from the pilot valve by unscrewing the manual control screw, counter-clockwise, see drawing 10-G-93 in the part entitled, "Air-0-Line Control Adjustments", in this section.

Clean out the small hole in the manual control screw by using a fine wire (0.008" diameter or less). The pen cleaners, supplied in the accessories with the instrument, can be used.

If the reducer is clogged and it is not practical to take the instrument off control for cleaning the reducer, the manual control can be adjusted to a point where the automatic control will continue to function. Turn the manual control in a counter-clockwise direction until proper automatic control is again obtained. The manual control screw need be turned only a small amount to accomplish this.

CAUTION: Do not turn the manual control screw too far in counter-clockwise direction as this will prevent the diaphragm valve pressure from dropping properly when the nozzle is uncovered.

For checking this adjustment move the control index in the direction to drop the diaphragm valve pressure and see if this pressure drops as it should.

K. THE PROGRAM CONTROL SYSTEM ADJUSTMENTS

For the purpose of explanation the program control system may be divided into two parts: the temperature control system, and the program control system.

1. Temperature Control

The temperature of the furnace is controlled at the point indicated by the position of the control index on the chart or scale, even though the control index may move up or down the scale.

This control may be effected through electrical means or through pneumatic means depending upon which has been selected as best for the particular application.

For further details of the temperature control system, please refer to the accompanying instructions for that type of control.

2. Adjusting the Equipment

The equipment which must be adjusted or set, before operating the program, is indicated on the external wiring diagram which accompanies these instructions. The various equipment may be set as follows:

The heating rate or cooling rate should first be set on the rate controllers. If the dials of the rate controllers are not calibrated directly in degrees per hour, the rates may easily be computed as follows:

If R = desired heating or cooling rate in degrees per hour
 S = speed of control point drive in inches per hour
 C = range of instrument chart or scale ($0-1000 = 1000$ degrees but $1000-3000 = 2000$ degrees)
 P = percentage of contact closure

then,

$$P = \frac{11 \times R}{C \times S} \times 100$$

If the contact closure of the rate controller is 0-100%, the dial may be set directly to the value P. If the contact closure of the rate controller used is 0-40%, the dial must be set to a value which is two and one-half times the value P.

It is suggested that the above equation be worked out completely for every 2% setting and a card made up listing the percentage settings opposite the result and heating or cooling rate. The card may be mounted near the rate controller for ready reference.

It is important to note that the **rate controllers should never be set below 10%** because below this setting there is a possibility that the accuracy will decrease.

Each soaking time controller should be set for the desired holding or "soaking" period. This may be done by simply turning the knob of the dial to the desired number of hours.

Further information for setting the soaking time controllers or rate controllers is contained in the instructions for those units.

The auxiliary switches must be set to determine the holding temperature or other points in the program. See the part entitled, "Setting the Auxiliary Switch", in this section.

The program control system should now be completely adjusted to provide the desired program sequence.

3. Starting the Program

Before starting the program, the points listed on the external wiring diagram for the control system should be checked carefully to determine if all of the auxiliary equipment is properly adjusted.

The control index should now be set to the desired starting temperature for the program.

Then if the control equipment, such as relays, motors, valves, etc. are properly connected, the line switch to the program control system may be thrown.

If all connections seem to be in proper order, the **RESET** button may be pushed. The program sequence will then follow.

Upon starting for the first time, it is well to run the program completely through without the control motors or valves operating and with the furnace unloaded. The operation of the program control system may then be closely checked by observation.

During the holding or "soaking" period when the control index is stationary at some point, the temperature control system may be turned on with the furnace unloaded to determine whether the control valves, etc. are properly adjusted.

4. Altering the Program Sequence

If it is desired to alter the entire arrangement of the program sequence - for instance, provide two or three holding periods in place of one, or provide two rates of rise where there is now one rate, - the nearest office of the Brown Instrument Company should be contacted.

The Brown Instrument Company will be pleased to detail the changes necessary in the system to provide additional functions.

L. SETTING THE AUXILIARY SWITCH

An auxiliary switch is supplied when ordered with the instrument. Dwg. 10-G-92 illustrates an auxiliary switch SPST, mounted on the left-hand sideplate and operating from the pen carriage spiral shaft. The switch is tilted when two slotted discs, driven by gears from the pen or control spiral shaft, come in alignment.

Referring again to Dwg. 10-G-92, the auxiliary switch may be adjusted to operate at any desired point on the scale as follows:

1. Turn the slotted hub (A) with a screwdriver until the three (3) red marks, M_1 , M_2 , and M_3 are in alignment. The proper direction to turn is determined by observing the marks M_1 and M_2 . If they are spreading instead of closing in, reverse the direction and keep turning until all of the marks come together. Several turns may be necessary.

When all red marks are in alignment it will be observed that the slotted discs are also in position to allow the switch to tilt if the spiral shaft (S) is turned.

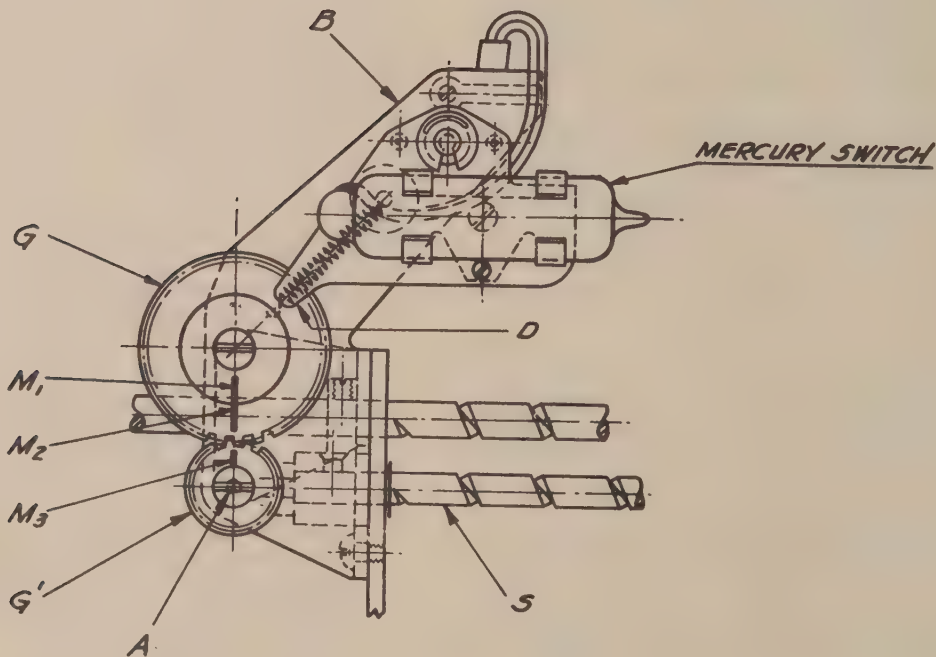
2. Hold the large upper gear (G) with the fingers of the left hand and turn the slotted hub (A) with a screwdriver against friction. As (A) is turned, the pen or control carriage moves up or down scale. Turn it until the index below the scale indicates the exact setting at which the auxiliary switch is to operate.

The auxiliary switch is now completely adjusted. Whenever it is desired to make a change in the setting, simply repeat operations (1) and (2) above.

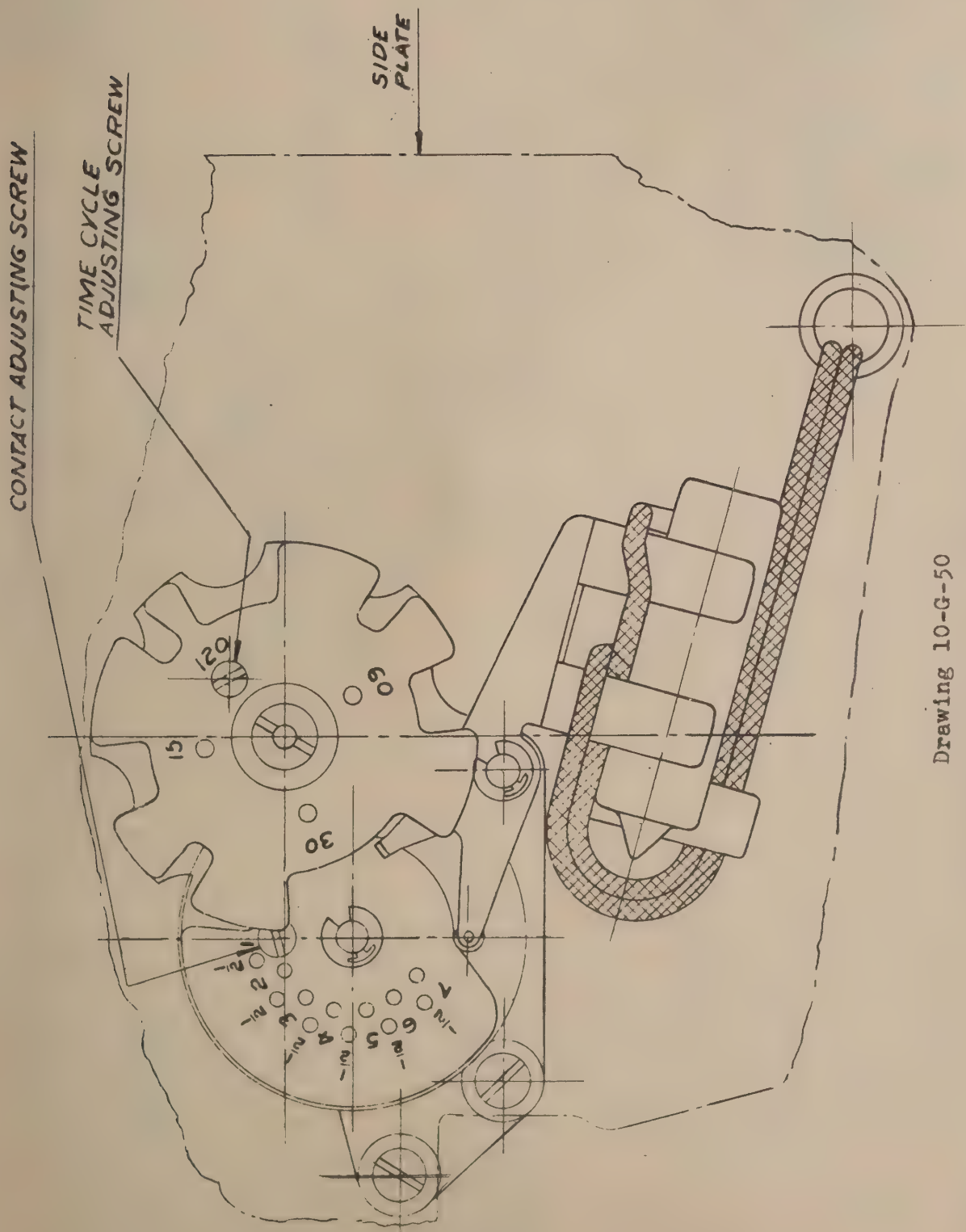
Section 1361
Page No. 14
of 15 Pages

M. THE INTERRUPTER SWITCH

The time cycle during which one contact is made and broken is changed by removing the screw in the right-hand disc and placing it in the hole opposite the time cycle desired.

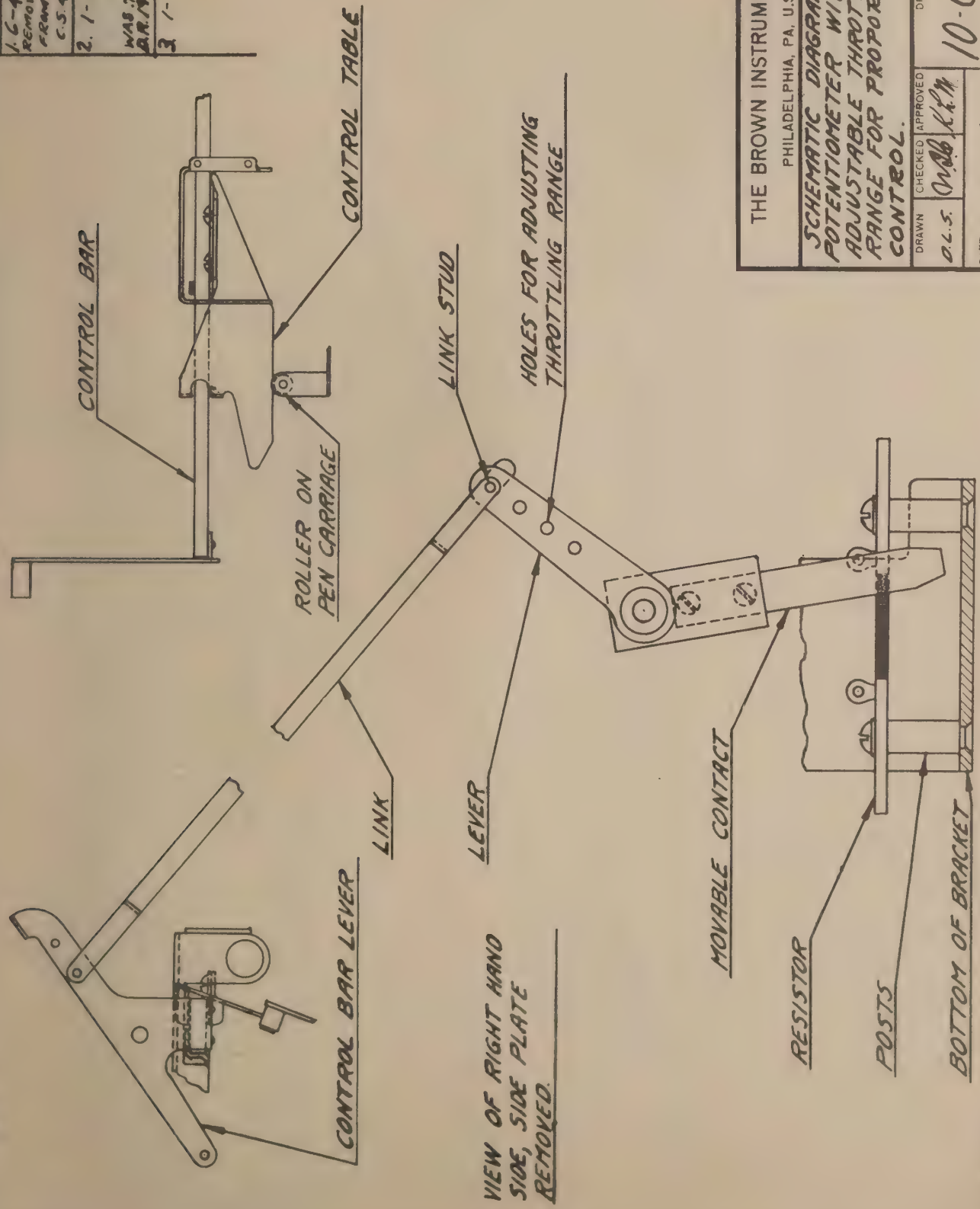


Drawing 10-G-92
Auxiliary Switch for Potentiometer



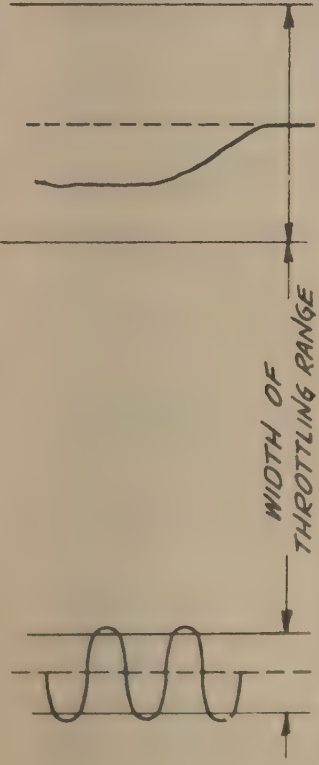
Drawing 10-G-50
Interrupter Switch for Potentiometer

15	10	APPROVED
1. 6-4-35	K.P.M.	REMOVED FROM TITLE
2. 1-6-43	E.F.	WAS 7A-47
3. 1-2-47	E.F.	BAR 192-1



THE BROWN INSTRUMENT CO. PHILADELPHIA, PA. U.S.A.	
SCHEMATIC DIAGRAM OF POTENTIOMETER WITH ADJUSTABLE THROTTLING RANGE FOR PROPORTIONING CONTROL.	
DRAWN O.L.S.	CHECKED APPROVED W.H.B. K.P.M.
DRAWING NO. 10-6-56	
DATE 6-4-35	

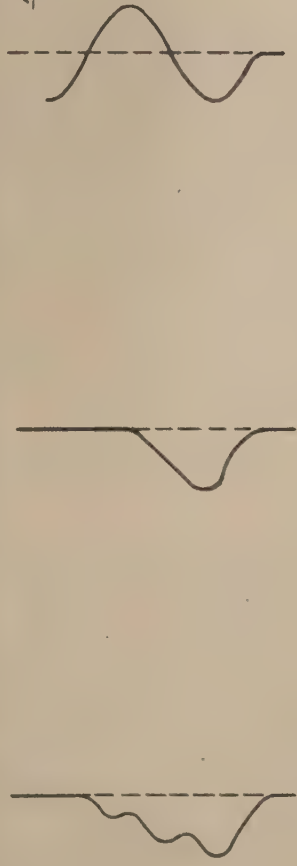
THROTTLING RANGE



TEMP OSCILLATES
THROTTLING RANGE TOO NARROW

TEMP DRIFTS
THROTTLING RANGE TOO WIDE

PROPORTIONATE RESET

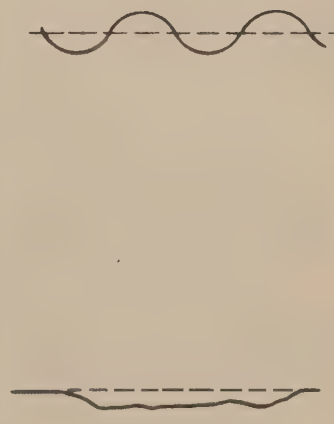


C2 SETTING
TOO LOW

C2 SETTING
CORRECT

C2 SETTING
TOO HIGH

TIMED RESET



C3 SETTING
TOO LOW

C3 SETTING
TOO HIGH

N.F.

THE BROWN INSTRUMENT CO.
PHILADELPHIA, PA, U.S.A.

EFFECT OF CONTROL
ADJUSTMENTS OF POTENTIAL
METER & BECK MECHANISM

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SECTION 1362
Issue 2MAINTENANCE OF THE BROWN TYPE 113 MECHANICAL
POTENTIOMETER AND RESISTANCE THERMOMETER

- A. Cleaning the Print Wheel
- B. Cleaning the Thermocouple Switches
- C. Cleaning the Slidewire
- D. Chart Replacement
- E. Standardizing
- F. Checking Mechanical Zero
- G. Maintenance of Dry Cells
- H. Maintenance of Standard Cells
- I. Servicing the Motor
- J. Maintenance of the Control Mechanisms

A. CLEANING THE PRINT WHEEL

Clean the numeral print wheel assembly each time the ink pads are replaced, or more frequently if necessary. Use a small, clean, dry brush with stiff bristles, such as a typewriter or tooth brush. Rotate the print wheel by means of the printing cam and ratchet assembly on the chart drum shaft at the right-hand side plate.

B. CLEANING THE THERMOCOUPLE SWITCHES

Clean the multiple switch contacts when renewing the chart and ribbon or ink pads.

CAUTION: Do not use abrasives on the switch contacts.

Unclip the base of the switch and lower it sufficiently to allow the oil to drain from the switch brushes. Then remove it entirely and empty the oil.

Clean the contacts and brushes with a brush and benzol or naphtha. Dry them with a lint-free rag. Take care not to bend the brushes.

Refill with immersion oil to cover the face of the contacts approximately 1/16 inch.

Replace the switch base.

C. CLEANING THE SLIDEWIRE

To obtain satisfactory operation, it is important to clean the slidewire approximately twice a year. Carefully follow these instructions when replacing old slidewire oil with new oil. Obtain slidewire immersion oil from the Brown Instruments Division. Do not use substitutes. All traces of the old oil must be removed from the slidewire before adding new oil. This cleaning operation is not necessary on new slidewires that are being put into operation for the first time, since it has been done at the factory before shipment.

1. Run the print hammer upscale against the stop. Carefully note the relative positions of the arrows on the two large bevel gears, located one above and one at the side of the slidewire. Maintenance of the correct relationship is important in obtaining the proper synchronism between the slidewire contactor position and the print hammer position. Normally, the arrow on the horizontal gear is displaced approximately one-half tooth toward the rear of the chassis from the arrow on the vertical gear.
2. Remove the slidewire assembly from the instrument by loosening the nine small screws on the back of the unit, removing the two large screws that clamp the unit to the metal frame, and lifting out the assembly.

DO NOT loosen any of the set screws used to fasten the bevel gears to their respective shafts, as this will throw the instrument out of mechanical adjustment.

3. Remove the two screws holding the standardizing switch cover to the slidewire and remove the cover. Wipe the contacts, brush, brush holder, and contact point of the load spring with a soft, lintless cloth saturated with alcohol or carbon tetrachloride. Then coat these points with a small amount of Brown Instruments Division lubricant type L-9. Replace the standardizing switch cover.
4. Remove the wire bail holding the glass jar to the slidewire unit, then lift the slidewire out of the jar. Hold the glass jar in an upright position to avoid spilling the oil.
5. Throw the oil away.
6. Rinse the slidewire unit and glass jar in commercial grade benzol or naphtha.

CAUTION: Benzol or naphtha should be used only where there is a good circulation of air to carry off the fumes, because these solvents are explosive, inflammable, and toxic.

7. Form a small piece of fine sand paper (No. 0000), into a roll of the same diameter as the contact roller. (Do not use emery or crocus.) Rub this lightly along the entire length of the slidewire and battery rheostat, touching all surfaces where the contact roller normally travels. Sand just enough to remove the film on the wire so that all turns are clean and bright. Do not actually remove metal as that would change the calibration.
8. Scrub the slidewire thoroughly with benzol or naphtha, using a small stiff brush. Brush in such a way that the bristles will remove all foreign particles between the turns of wire.

9. Rinse the unit with clear benzol or naphtha. Do not use dirty benzol or naphtha for this last rinse. Shake off excess cleaning liquid and allow the unit to air dry for at least fifteen minutes.
10. Replace the slidewire inside the jar; then hook the bail to the moulding and lock it. Be sure that the locking lever on the bail is pointed toward the front of the instrument when the slidewire assembly is replaced.
11. Before replacing the slidewire assembly in the instrument, turn the bevel gear moving the contactor from one end of the slide to the other. If the contactor jams at any point, shift the glass jar with respect to the slidewire until the contactor is free over the full length of its travel.
12. Run the print hammer up scale against the stop. Turn the slidewire bevel gear in a clockwise direction until the contactor is at the top end of the slidewire.
13. Then place the slidewire assembly in the frame, making sure that the arrows on the bevel gears are lined up as they were when the assembly was removed. Tighten the two screws holding the slidewire assembly to the frame and the 9 small screws on the back of the unit.
14. Fill the slidewire jar with new immersion oil to the oil level line. Replace the screw plug.

D. CHART REPLACEMENT ON RECORDERS

Renew the chart as required. The word RENEW is stamped on the chart every 6 inches with the first mark appearing 96 inches before the chart runs out. At a chart speed of 2 inches per hour, the chart will last for 48 hours from the time the first mark appears.

To remove the chart, push the bottom leaf spring on the right-hand side plate away from the side plate just far enough to release the re-rolled chart. When installing a new chart, push the top leaf spring on the right-hand side plate away from the side plate enough to release the metal tube, then slide off the cardboard tube left from the old chart. Slide the metal tube through new chart, letting the tube extrude about 1 inch on the left side. Place the extruded end of the tube on the chart disc in the left-hand side plate. Next slide the chart all the way over the tube and push the top leaf spring away from the side plate until the right end of the metal tube can be slipped in place: then release the spring.

Lead the paper up and over the driving drum from the back, and thread it between the tear-off glass and the writing platen, making sure that the pins in the chart drum are engaging the chart paper. The chart paper can then be fed forward by turning the large knob on the chart drum shaft.

Section 1362

Page No. 4

Place the cardboard tube left over from the previous chart between the chart reroll discs by pushing the bottom leaf spring away from the side plate until the tube can be slipped into position. Then fasten the starting end of the new chart to the cardboard tube by means of the sticker found on the new chart. Be sure, before fastening the chart, that the pull on it is evenly divided across its width.

When ordering new charts, always specify the chart number which is marked on the margin.

E. STANDARDIZING

Restandardize the pyrometer battery current once a day.

Push the switch lever to the extreme left "Bal." position with one finger, and turn the knurled disc above it with the thumb until the step of the galvanometer step table indicated by the BLACK arrow contacts the pointer.

The current from a new battery drops off rapidly for the first day or two. During this period the instrument should be standardized several times a day, after which it will be necessary only once a day. Replace batteries when the standardizing rheostat has reached the end of its travel and the instrument can no longer be standardized.

Resistance thermometers do not require standardizing.

F. CHECKING MECHANICAL ZERO

Check the mechanical zero once a week.

While the motor is running, push the switch lever on the slidewire unit to its center ZERO position, and turn the zero adjusting screw on the front of the galvanometer cover so that the step of the galvanometer step table indicated by the small BLACK arrow contacts the galvanometer pointer.

G. MAINTENANCE OF DRY CELLS

In resistance thermometer instruments, replace the dry cells every four months.

In Brown Potentiometers, replace the cells when the instrument can no longer be standardized.

When temperatures below 32°F or above 140°F are encountered, remove the dry cell to a location where the temperature is moderate (approximately 75°F) and run the necessary wires to the battery terminals inside the instrument.

The proper number of cells to be used for a given instrument is covered in the tables in the Section entitled, "Description and Data on Component Parts of Type 113 Mechanical Potentiometer".

H. MAINTENANCE OF STANDARD CELLS

When temperatures below 32°F or above 140°F are likely to be encountered, remove the standard cell from the instrument and place it in a location where the temperature is moderate (approximately 75°F). Use copper wire of No. 18 gauge or larger, and observe the polarity marks. These wires can follow the measuring circuit cable across the frame to the hinges on the side of the case, then out through a conduit. Fasten the wires to the standard cell leads by means of the terminal screws in the tapped terminal clip. Tape the connections to avoid short circuiting.

CAUTION: Take care to prevent breakage when removing the cell and in placing it in the new location. Place it with the terminals at the bottom and do not set the cell on any metal, as the terminals will be shorted.

I. SERVICING THE MOTOR

Potentiometer motors should be inspected, cleaned, and relubricated after one year of service.

When disassembling the motor, note the positions of all shims, washers, and other parts. They must be replaced in their former positions when the motor is being assembled in order to line up the rotor and bearings. Failure to observe this may cause binding and noise, and may result in premature failure of the motor.

The motor used will be either an Emerson or a Robbins and Myers. For either, proceed as follows:

1. Remove both end bells from the motor frame by removing three screws from the gear case side and four screws from the opposite side. Then withdraw the armature from the housing.
2. Do not attempt to remove the rotor bearings.

The Robbins and Myers rotor bearings are hermetically sealed and cannot be relubricated. On an Emerson rotor, wash the bearings with gasoline and inspect them for excessive wear. Repack each bearing with one-half level teaspoonful of special grease which can be obtained from the Brown Instruments Division.

3. Remove from the gear case both the gear case cover and the vertical gear shaft cover adjacent to it.
4. Remove as much grease as possible from the gear case with a small flat piece of wood. Wash out the case and vertical shaft bearing

thoroughly with gasoline. Do not use kerosene as it may collect in pockets and dilute the new grease.

5. Inspect gears and bearings for excessive wear.
6. For new grease, use a sodium base non-tracking grease obtainable from the Brown Instruments Division. Vigorously churn it with a spoon or a small wooden paddle, until it becomes stringy. Then fill the gear case to the top of the output shaft bearing. Apply a small amount of grease to the vertical shaft ball bearing and force it into the spaces in the race.
7. Clean the housing, rotor, and end bells of all dirt and grease. Do not disturb the capacitor connections except in replacing capacitors. Insert the rotor into the motor housing and fasten the two end bells in place.
8. Check for end play. There should be approximately .010 inch end play in the rotor after the motor has been assembled. Should the end play exceed .020 inch, it is an indication that shims have been omitted in reassembling the motor or that wear has taken place: insert additional shims to reduce the end play to approximately .010". Check for excessive wear on the output shaft. Apply a few drops of light machine oil to the bearing oil cup.
9. Shellac a new gasket to the top of the gear case. Also fasten the vertical shaft cover in place.

J. MAINTENANCE OF THE CONTROL MECHANISMS

The automatic control mechanisms require very little maintenance. A little experience is necessary to determine the frequency of inspection. The establishment of a periodic schedule of inspection is recommended.

1. Mercury Switch Control System

If the mercury switch fails to open or close the circuit, inspect the glass tube to see whether it has been broken or cracked. A crack in the glass tube will result in a smoky appearance and the switch should be replaced. On the curved type mercury switch, improper action is sometimes caused by not having the instrument mounted in a level position.

If the switch selections appear to be erratic, check the switch assembly. Make sure that the switch shaft does not turn and that the individual switches have sufficient friction on the hubs to hold them in whatever position they are placed.

Each mercury switch supporting clip is provided with a friction washer to hold the switch in whatever position it may be pushed by the control

fingers. Check the friction on these cup washers and make sure that it is sufficient to hold the switch after it has been tilted by the control mechanism.

2. M-H Proportioning Control System

a. Cleaning the Contact and the Resistance Element

(1) In the Instrument

The resistance element and the contact are located on the rear of the chassis at the lower right-hand side and are exposed to view by swinging the chassis out of the case.

Keep the movable contact and the working portion of the resistance element clean at all times. The materials are corrosion-resistant and, if kept clean, will function with reliability. A periodic inspection at monthly intervals is recommended.

The pressure between the contact and the resistance element in the controller should be checked occasionally. If the contact pressure is too low, electrical continuity will not be maintained; if it is too high, excessive wear will result.

The contact pressure should be between 1 1/2 and 2 ounces. If it is outside those limits, adjust it by swinging the contact arm completely off the resistance element assembly and then bending the contact arm to increase or decrease the pressure as required.

(2) In the Proportioning Motor

The resistor and contactor in the proportioning motor should need no attention for the life of the motor.

b. Lubrication

The gear unit of the proportioning motor is packed in grease and should require no attention during the normal life of the motor.

Oil the motor bearings once each year. Use a good grade light oil and apply a few drops to the two oil holes in the motor housing.

NOTE: Never use a heavy commercial grade of oil on the proportioning motor. Use a light, good quality instrument oil.

3. M-H Proportioning Relay

This section covers the maintenance of the M-H proportioning relay. The procedure outlined in the following paragraphs should be followed

Section 1362

Page No. 8

whenever the relay fails to operate satisfactorily as a result of sticking or continuous arcing of the relay contacts.

NOTE: In the following paragraphs, reference is made to the pilot relay and the load relay, both of which are parts of the proportioning relay. The two relays can be identified by looking for the cross-shaped phosphor-bronze damping spring which is mounted on the armature of the load relay only.

a. Cleaning Relay Contacts

Clean the relay contacts by rubbing a strip of clean, rough, unglazed paper back and forth between the contacts of each set while holding the armature down on the proper side. Do not use abrasive paper or cloth unless the contacts are extremely dirty. If such paper is used, select only the finest grade and use it carefully. VIOLENT RUBBING IS UNNECESSARY.

If the load relay contacts are badly burned it may be necessary to use a small, fine file to clean them. Always use fine grade abrasive cloth or paper after filing. It should never be necessary to use a file on the pilot relay contacts.

After using abrasive paper always clean the contacts with rough paper or cloth to remove all grit and loose metal particles.

b. Adjustment of Relay Contacts

Adjust the pilot relay contact gaps to .010 inch total, and the contact gaps for the load relay to .050 inch total. With no power on the relay the gap should be equally divided on either side of the contact blade. Bend the blade to make the spacing correct.

c. Test Operation

After the above procedure, the relay should be ready for operation. Connect the relay to the power line, motor, and instrument so that the operation can be tested.

The load relay contact should always snap to approximately its center position without sticking to either side on breaks, should not buzz or arc continuously when making contact on either side, and should not chatter excessively.

If the load relay contacts buzz or chatter excessively, check to make certain that the pilot relay contacts are clean.

If the valve motor hunts, even though the load relay operates correctly as described above, the relay may be too sensitive. This condition may be corrected by unscrewing one or the other of the pilot relay contacts a quarter of a turn at a time until the hunting stops. Usually a one-half turn wider setting of the pilot relay contact gaps will be sufficient to prevent hunting.

4. A.T.C. Relatrol Relay of the Electronic Type

a. The Electron Tubes

These are standard radio tubes which are operated considerably below their nominal ratings in order to insure trouble-free performance.

Replacement tubes may be purchased from any local radio parts dealer.

It is recommended that the tubes be replaced every six months.

NOTE: For most satisfactory performance replace both tubes at the same time.

After replacing tubes, recheck the relay sensitivity, as described in the part, "Adjusting the Relatrol Relay Sensitivity", in the section entitled, "Control Adjustments and Corrective Data".

The Bridge Relay is a part of the Relatrol Relay. It is an easily removable unit which is plugged into a socket at the top of the Relatrol Relay chassis. The contacts are enclosed and normally do not require any attention.

Should the system fail to operate because of failure of the bridge relay to operate properly, it is recommended that the bridge relay be replaced by a new unit and that the old unit be returned to the manufacturer for repairs.

5. Air Control Systems

A clean and dry air supply to the system should be maintained. Where liquids (oil and water) in the air supply are excessive, partially open the petcock at the bottom of the filter in order to provide a continuous drain. Replace the filtering material in the filter periodically, the frequency depending on local conditions.

All controlled valves used with the air operated controller must be equipped with stem lubricator. The lubricant used should apply to the particular fluid being controlled and should be inserted before putting valve into service. Never tighten the stuffing box to stop leakage; insert more lubricant instead.

6. The Beck Mechanism

The resistor and contactor in the Beck Mechanism need no attention for the life of the motor.

a. Lubrication(1) Beck Mechanism

The inside of this unit is greased to permit approximately five years of service without attention. The motor is equipped with grease-sealed ball bearings, and since the motor's speed is only 75 rpm, the bearings should last for the life of the unit without attention. Twice a year inspect the control mechanism under the deep cover where the slidewire and limit switches are located and place a few drops of oil on the ratchet and pawls.

CAUTION: Do not allow oil to get on the slidewire.

(2) Control Valve

If the control valve is provided with a means of lubrication, lubricate it. If the fuel is gas which contains coal tar, ordinary lard is a very effective lubricant and a great aid in cleaning a valve that may have become plugged with tar deposits.

Accumulations of tar in the valve port will change the rangeability of the control and should not be allowed to build up.

7. A.T.C. Balancer and Relatrola. The Valve Operator

The resistor and contactor in the valve operator should need no attention for the life of the unit.

b. Cleaning the Relay Contacts

The contacts of the Bridge Relay, which is a part of the Balancer Relay, should be cleaned with a fine contact-file every three months, or more often if the unit is installed in a dusty or gaseous atmosphere.

Inspect the contact arm occasionally to see that it is properly balanced. Turn off the power switch before making this inspection. The contact arm should assume a mid-position between the contacts. If it does not, slightly move the pigtail wire connected to the contact arm, to bring the arm to mid-position.

In addition to the above contacts, the Balancer Control system has a single-pole double-throw contact labeled "Load Compensation". Regularly inspect this contact and clean it if necessary.

c. Lubrication

Lubricate the valve operator every six months with a good grade of light machine oil. Refer to instructions furnished with the mechanism for the location of points requiring lubrication.

8. Program Control

From time to time, and frequently if the atmosphere is dusty or dirty, carefully clean the contacts of any relays with a soft cloth.

Every six months cover the relay contacts with a very thin film of vaseline or similar jelly. Also give the relay shaft a drop of oil at this time.

The auxiliary switch mechanism should require no attention or lubrication throughout its life.

The control point drive mechanism should require little attention beyond a periodic lubrication of the moving parts with a good grade of light oil, approximately every six months. The self-contained motor and gear reduction is lubricated and sealed and requires no further attention.

The individual instructions for the soaking time controllers and rate controllers indicate the necessary maintenance for those units.

9. Auxiliary and Interrupter Switches

Add a few drops of oil on the roller and bearing of the switch bracket once a month.

No additional maintenance should be necessary throughout the normal life of the instrument. If the mercury switch should be damaged by overloading, order a replacement switch. On the order, state the model number of the instrument, which appears on the nameplate.

10. Repairs and Service

If parts are necessary for repair, order them by specifying the serial number or part number. If this information is not available, include a description of the part together with the serial number of the assembly.

In requesting information regarding any instrument or one of the accessories, submit all the data contained on the nameplate.

SECTION 1309
Issue 1Section 1309
Page No. 1
of 5 PagesLUBRICATION OF THE BROWN TYPE 113 POTENTIOMETER
PYROMETER AND RESISTANCE THERMOMETER

Adding a drop of oil occasionally on all bearing surfaces and keeping the instrument clean at all times will add immeasurably to the life of the instrument and related parts.

The frequency of oiling and cleaning will depend on the operating temperatures and amount of dust and dirt which may get into the instrument. Under average conditions, oiling and general cleaning once a month with a thorough cleaning once a year will be satisfactory.

A. LUBRICATING THE INSTRUMENT

Lubricate all bearings and sliding surfaces monthly with a light oil preferably the instrument oil - our Type L-1.

The exception to the above is the sliding contact between the two drive pawls and also between the secondary pointer positioner and the table cam lever. These sliding surfaces should be dry and clean in order to operate properly. After lubricating, check these surfaces and wipe with a clean rag; also wipe off dirt and excess oil on the side plate.

Oil the ball bearing kidney cam follower on the step lever with our oil Type L-1 or equivalent and pack all other roller or ball bearings with our grease Type L-7 or equivalent.

Figures 1309-1, 2, 3, and 4 are charts showing the main bearings to be lubricated once each month.

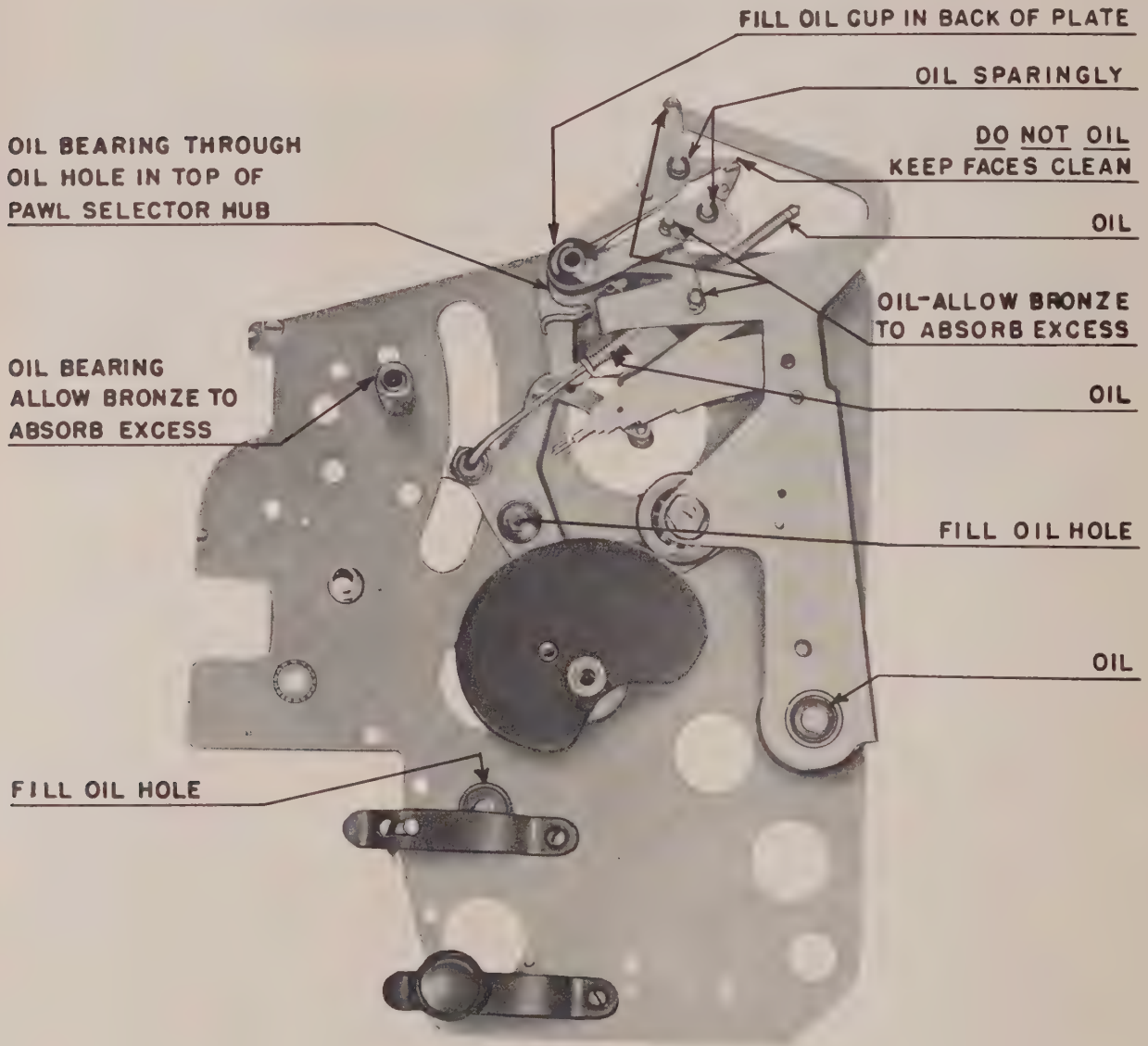


Figure 1309-1 - Oiling Chart
Right-Hand Side Plate of Single
Record Mechanical Potentiometer

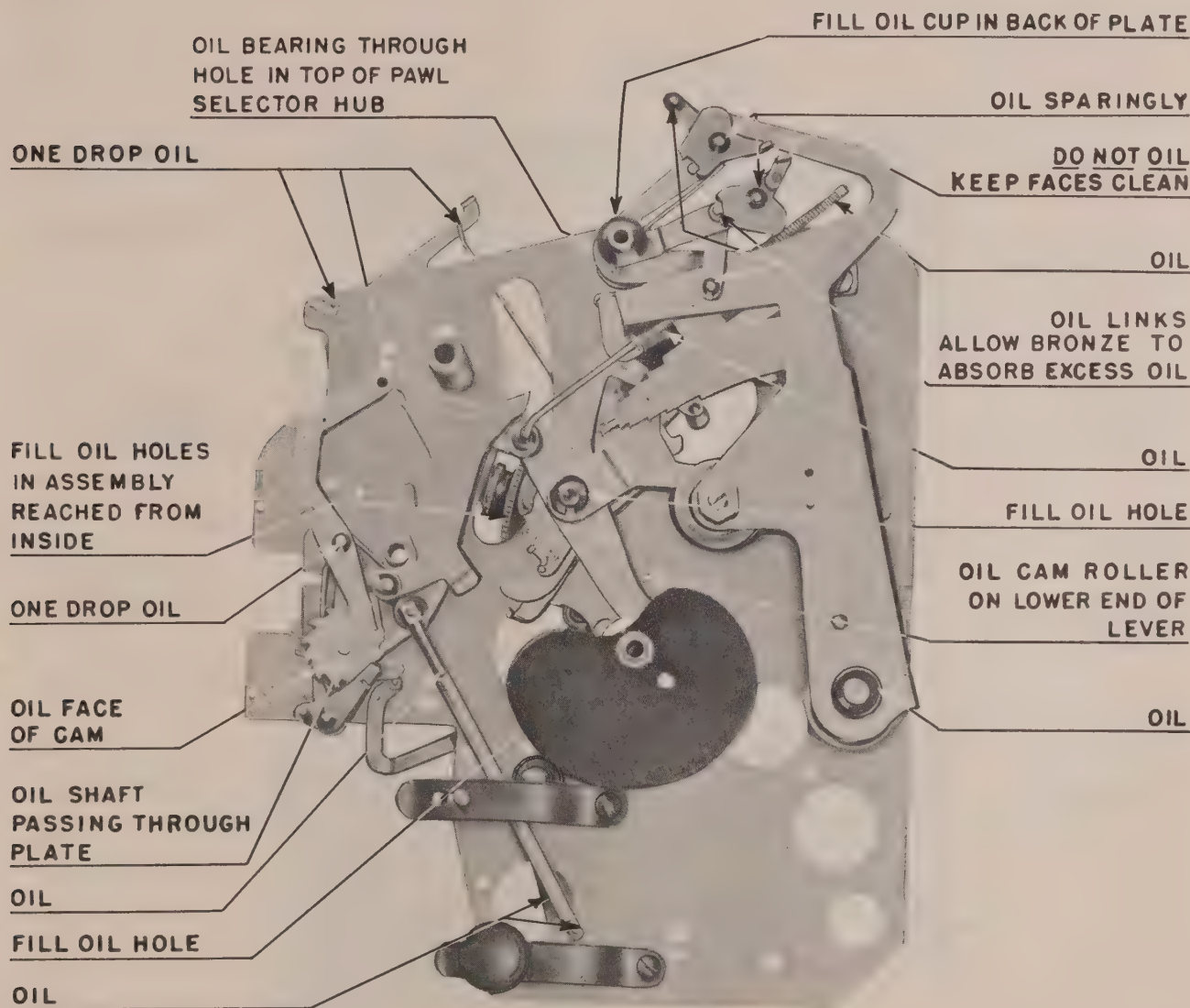


Figure 1309-2 - Oiling Chart
Right-Hand Side Plate of Multiple
Print Hammer Mechanical Potentiometer

Page No. 4



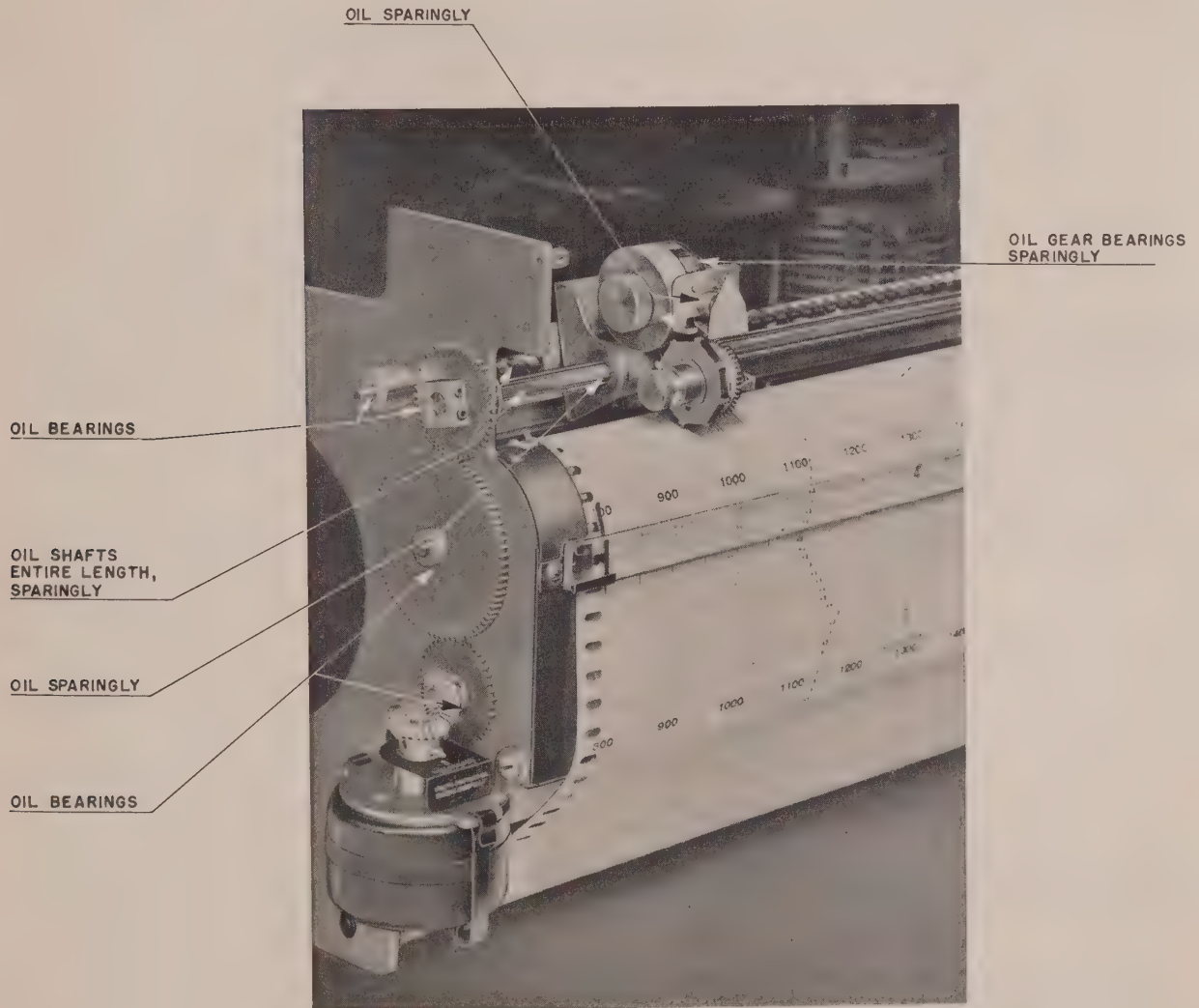


Figure 1309-4 - Oiling Chart
Left-Hand Side Plate and
Print Wheel Carriage of Multiple
Print Wheel Mechanical Potentiometer

SECTION 1137

Issue 4

THERMOCOUPLE
TEMPERATURE-MILLIVOLT EQUIVALENTS

Fahrenheit - Pages 3 to 14 inclusive

Centigrade - Pages 15 to 26 inclusive

Instructions for using the tables on the following pages:

1. TO CONVERT MILLIVOLTAGE TO EQUIVALENT TEMPERATURE

Assume that the emf of an I.C. thermocouple with cold junction temperature of 70°F is found to be 26.50 millivolts. Correct this reading to its equivalent with cold junction temperature of 32°F by adding 1.10 millivolts, the equivalent of 70°F in the I.C. temperature-millivolt table based on 32°F cold junction. This table is shown on page 7.

The corrected reading is $26.50 + 1.10 = 27.60$ millivolts. Reference to the same table or the one on page 8 (with proper interpolation as indicated at the bottom of the table) indicates that the equivalent temperature is 939°F.

Note that the correction is added. It is obvious that the millivoltage for a given hot junction temperature is greater at the lower cold junction temperature on which the table is based.

Tables for other standard thermocouples are used in a similar manner.

2. TO CONVERT TEMPERATURE TO EQUIVALENT MILLIVOLTAGE

Assume that it is desired to check a potentiometer calibrated for M.A. thermocouple at 1450°F. The cold junction temperature at the terminals of the potentiometer is found to be 70°F.

From the table on page 9, it is found that 1450°F = 32.80 millivolts. 70°F is found to equal 0.84 millivolts. The millivoltage to be applied to the instrument is $32.80 - 0.84 = 31.96$ millivolts. Note that the correction is subtracted in this case where the actual cold junction temperature is higher than 32°F, since the millivoltage produced by a thermocouple decreases as the cold junction temperature increases.

Conversion of Centigrade and Fahrenheit Scales

For temperatures above 0° C.

Temp. °C.	0	1	2	3	4	5	6	7	8	9
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2
100	212.0	213.8	215.6	217.4	219.2	221.0	222.8	224.6	226.4	228.2
110	230.0	231.8	233.6	235.4	237.2	239.0	240.8	242.6	244.4	246.2
120	248.0	249.8	251.6	253.4	255.2	257.0	258.8	260.6	262.4	264.2
130	266.0	267.8	269.6	271.4	273.2	275.0	276.8	278.6	280.4	282.2
140	284.0	285.8	287.6	289.4	291.2	293.0	294.8	296.6	298.4	300.2
150	302.0	303.8	305.6	307.4	309.2	311.0	312.8	314.6	316.4	318.2
160	320.0	321.8	323.6	325.4	327.2	329.0	330.8	332.6	334.4	336.2
170	338.0	339.8	341.6	343.4	345.2	347.0	348.8	350.6	352.4	354.2
180	356.0	357.8	359.6	361.4	363.2	365.0	366.8	368.6	370.4	372.2
190	374.0	375.8	377.6	379.4	381.2	383.0	384.8	386.6	388.4	390.2
200	392.0	393.8	395.6	397.4	399.2	401.0	402.8	404.6	406.4	408.2
210	410.0	411.8	413.6	415.4	417.2	419.0	420.8	422.6	424.4	426.2
220	428.0	429.8	431.6	433.4	435.2	437.0	438.8	440.6	442.4	444.2
230	446.0	447.8	449.6	451.4	453.2	455.0	456.8	458.6	460.4	462.2
240	464.0	465.8	467.6	469.4	471.2	473.0	474.8	476.6	478.4	480.2
250	482.0	483.8	485.6	487.4	489.2	491.0	492.8	494.6	496.4	498.2
260	500.0	501.8	503.6	505.4	507.2	509.0	510.8	512.6	514.4	516.2
270	518.0	519.8	521.6	523.4	525.2	527.0	528.8	530.6	532.4	534.2
280	536.0	537.8	539.6	541.4	543.2	545.0	546.8	548.6	550.4	552.2
290	554.0	555.8	557.6	559.4	561.2	563.0	564.8	566.6	568.4	570.2
300	572.0	573.8	575.6	577.4	579.2	581.0	582.8	584.6	586.4	588.2
310	590.0	591.8	593.6	595.4	597.2	599.0	600.8	602.6	604.4	606.2
320	608.0	609.8	611.6	613.4	615.2	617.0	618.8	620.6	622.4	624.2
330	626.0	627.8	629.6	631.4	633.2	635.0	636.8	638.6	640.4	642.2
340	644.0	645.8	647.6	649.4	651.2	653.0	654.8	656.6	658.4	660.2
350	662.0	663.8	665.6	667.4	669.2	671.0	672.8	674.6	676.4	678.2
360	680.0	681.8	683.6	685.4	687.2	689.0	690.8	692.6	694.4	696.2
370	698.0	699.8	701.6	703.4	705.2	707.0	708.8	710.6	712.4	714.2
380	716.0	717.8	719.6	721.4	723.2	725.0	726.8	728.6	730.4	732.2
390	734.0	735.8	737.6	739.4	741.2	743.0	744.8	746.6	748.4	750.2
400	752.0	753.8	755.6	757.4	759.2	761.0	762.8	764.6	766.4	768.2
410	770.0	771.8	773.6	775.4	777.2	779.0	780.8	782.6	784.4	786.2
420	788.0	789.8	791.6	793.4	795.2	797.0	798.8	800.6	802.4	804.2
430	806.0	807.8	809.6	811.4	813.2	815.0	816.8	818.6	820.4	822.2
440	824.0	825.8	827.6	829.4	831.2	833.0	834.8	836.6	838.4	840.2
450	842.0	843.8	845.6	847.4	849.2	851.0	852.8	854.6	856.4	858.2
460	860.0	861.8	863.6	865.4	867.2	869.0	870.8	872.6	874.4	876.2
470	878.0	879.8	881.6	883.4	885.2	887.0	888.8	890.6	892.4	894.2
480	896.0	897.8	899.6	901.4	903.2	905.0	906.8	908.6	910.4	912.2
490	914.0	915.8	917.6	919.4	921.2	923.0	924.8	926.6	928.4	930.2
500	932.0	933.8	935.6	937.4	939.2	941.0	942.8	944.6	946.4	948.2
510	950.0	951.8	953.6	955.4	957.2	959.0	960.8	962.6	964.4	966.2
520	968.0	969.8	971.6	973.4	975.2	977.0	978.8	980.6	982.4	984.2
530	986.0	987.8	989.6	991.4	993.2	995.0	996.8	998.6	1000.4	1002.2
540	1004.0	1005.8	1007.6	1009.4	1011.2	1013.0	1014.8	1016.6	1018.4	1020.2
550	1022.0	1023.8	1025.6	1027.4	1029.2	1031.0	1032.8	1034.6	1036.4	1038.2
560	1040.0	1041.8	1043.6	1045.4	1047.2	1049.0	1050.8	1052.6	1054.4	1056.2
570	1058.0	1059.8	1061.6	1063.4	1065.2	1067.0	1068.8	1070.6	1072.4	1074.2
580	1076.0	1077.8	1079.6	1081.4	1083.2	1085.0	1086.8	1088.6	1090.4	1092.2
590	1094.0	1095.8	1097.6	1099.4	1101.2	1103.0	1104.8	1106.6	1108.4	1110.2
600	1112.0	1113.8	1115.6	1117.4	1119.2	1121.0	1122.8	1124.6	1126.4	1128.2
610	1130.0	1131.8	1133.6	1135.4	1137.2	1139.0	1140.8	1142.6	1144.4	1146.2
620	1148.0	1149.8	1151.6	1153.4	1155.2	1157.0	1158.8	1160.6	1162.4	1164.2
630	1166.0	1167.8	1169.6	1171.4	1173.2	1175.0	1176.8	1178.6	1180.4	1182.2
640	1184.0	1185.8	1187.6	1189.4	1191.2	1193.0	1194.8	1196.6	1198.4	1200.2
650	1202.0	1203.8	1205.6	1207.4	1209.2	1211.0	1212.8	1214.6	1216.4	1218.2
660	1220.0	1221.8	1223.6	1225.4	1227.2	1229.0	1230.8	1232.6	1234.4	1236.2
670	1238.0	1239.8	1241.6	1243.4	1245.2	1247.0	1248.8	1250.6	1252.4	1254.2
680	1256.0	1257.8	1259.6	1261.4	1263.2	1265.0	1266.8	1268.6	1270.4	1272.2
690	1274.0	1275.8	1277.6	1279.4	1281.2	1283.0	1284.8	1286.6	1288.4	1290.2
700	1292.0	1293.8	1295.6	1297.4	1299.2	1301.0	1302.8	1304.6	1306.4	1308.2
710	1310.0	1311.8	1313.6	1315.4	1317.2	1319.0	1320.8	1322.6	1324.4	1326.2
720	1328.0	1329.8	1331.6	1333.4	1335.2	1337.0	1338.8	1340.6	1342.4	1344.2
730	1346.0	1347.8	1349.6	1351.4	1353.2	1355.0	1356.8	1358.6	1360.4	1362.2
740	1364.0	1365.8	1367.6	1369.4	1371.2	1373.0	1374.8	1376.6	1378.4	1380.2
750	1382.0	1383.8	1385.6	1387.4	1389.2	1391.0	1392.8	1394.6	1396.4	1398.2
760	1400.0	1401.8	1403.6	1405.4	1407.2	1409.0	1410.8	1412.6	1414.4	1416.2
770	1418.0	1419.8	1421.6	1423.4	1425.2	1427.0	1428.8	1430.6	1432.4	1434.2
780	1436.0	1437.8	1439.6	1441.4	1443.2	1445.0	1446.8	1448.6	1450.4	1452.2
790	1454.0	1455.8	1457.6	1459.4	1461.2	1463.0	1464.8	1466.6	1468.4	1470.2
800	1472.0	1473.8	1475.6	1477.4	1479.2	1481.0	1482.8	1484.6	1486.4	1488.2
810	1490.0	1491.8	1493.6	1495.4	1497.2	1499.0	1500.8	1502.6	1504.4	1506.2
820	1508.0	1509.8	1511.6	1513.4	1515.2	1517.0	1518.8	1520.6	1522.4	1524.2
830	1526.0	1527.8	1529.6	1531.4	1533.2	1535.0	1536.8	1538.6	1540.4	1542.2
840	1544.0	1545.8	1547.6	1549.4	1551.2	1553.0	1554.8	1556.6	1558.4	1560.2
850	1562.0	1563.8	1565.6	1567.4	1569.2	1571.0	1572.8	1574.6	1576.4	1578.2
860	1580.0	1581.8	1583.6	1585.4	1587.2	1589.0	1590.8	1592.6	1594.4	1596.2
870	1598.0	1599.8	1601.6	1603.4	1605.2	1607.0	1608.8	1610.6	1612.4	1614.2
880	1616.0	1617.8	1619.6	1621.4	1623.2	1625.0	1626.8	1628.6	1630.4	1632.2
890	1634.0	1635.8	1637.6	1639.4	1641.2	1643.0	1644.8	1646.6	1648.4	1650.2

For temperatures above 0° C.

temp. °C.	0	1	2	3	4	5	6	7	8	9
900	1652.0	1653.8	1655.6	1657.4	1659.2	1661.0	1662.8	1664.6	1666.4	1668.2
910	1670.0	1671.8	1673.6	1675.4	1677.2	1679.0	1680.8	1682.6	1684.4	1686.2
920	1688.0	1689.8	1691.6	1693.4	1695.2	1697.0	1698.8	1700.6	1702.4	1704.2
930	1706.0	1707.8	1709.6	1711.4	1713.2	1715.0	1716.8	1718.6	1720.4	1722.2
940	1724.0	1725.8	1727.6	1729.4	1731.2	1733.0	1734.8	1736.6	1738.4	1740.2
950	1742.0	1743.8	1745.6	1747.4	1749.2	1751.0	1752.8	1754.6	1756.4	1758.2
960	1760.0	1761.8	1763.6	1765.4	1767.2	1769.0	1770.8	1772.6	1774.4	1776.2
970	1778.0	1779.8	1781.6	1783.4	1785.2	1787.0	1788.8	1790.6	1792.4	1794.2
980	1796.0	1797.8	1799.6	1801.4	1803.2	1805.0	1806.8	1808.6	1810.4	1812.2
990	1814.0	1815.8	1817.6	1819.4	1821.2	1823.0	1824.8	1826.6	1828.4	1830.2
1000	1832.0	1833.8	1835.6	1837.4	1839.2	1841.0	1842.8	1844.6	1846.4	1848.2
1010	1850.0	1851.8	1853.6	1855.4	1857.2	1859.0	1860.8	1862.6	1864.4	1866.2
1020	1868.0	1869.8	1871.6	1873.4	1875.2	1877.0	1878.8	1880.6	1882.4	1884.2
1030	1886.0	1887.8	1889.6	1891.4	1893.2	1895.0	1896.8	1898.6	1900.4	1902.2
1040	1904.0	1905.8	1907.6	1909.4	1911.2	1913.0	1914.8	1916.6	1918.4	1920.2
1050	1922.0	1923.8	1925.6	1927.4	1929.2	1931.0	1932.8	1934.6	1936.4	1938.2
1060	1940.0	1941.8	1943.6	1945.4	1947.2	1949.0	1950.8	1952.6	1954.4	1956.2
1070	1958.0	1959.8	1961.6	1963.4	1965.2	1967.0	1968.8	1970.6	1972.4	1974.2
1080	1976.0	1977.8	1979.6	1981.4	1983.2	1985.0	1986.8	1988.6	1990.4	1992.2
1090	1994.0	1995.8	1997.6	1999.4	2001.2	2003.0	2004.8	2006.6	2008.4	2010.2
1100	2012.0	2013.8	2015.6	2017.4	2019.2	2021.0	2022.8	2024.6	2026.4	2028.2
1110	2030.0	2031.8	2033.6	2035.4	2037.2	2039.0	2040.8	2042.6	2044.4	2046.2
1120	2048.0	2049.8	2051.6	2053.4	2055.2	2057.0	2058.8	2060.6	2062.4	2064.2
1130	2068.0	2069.8	2071.6	2073.4	2075.2	2077.0	2078.8	2080.6	2082.4	2084.2
1140	2084.0	2085.8	2087.6	2089.4	2091.2	2093.0	2094.8	2096.6	2098.4	2100.2
1150	2102.0	2103.8	2105.6	2107.4	2109.2	2111.0	2112.8	2114.6	2116.4	2118.2
1160	2120.0	2121.8	2123.6	2125.4	2127.2	2129.0	2130.8	2132.6	2134.4	2136.2
1170	2138.0	2139.8	2141.6	2143.4	2145.2	2147.0	2148.8	2150.6	2152.4	2154.2
1180	2156.0	2157.8	2159.6	2161.4	2163.2	2165.0	2166.8	2168.6	2170.4	2172.2
1190	2174.0	2175.8	2177.6	2179.4	2181.2	2183.0	2184.8	2186.6	2188.4	2190.2
1200	2192.0	2193.8	2195.6	2197.4	2199.2	2201.0	2202.8	2204.6	2206.4	2208.2
1210	2210.0	2211.8	2213.6	2215.4	2217.2	2219.0	2220.8	2222.6	2224.4	2226.2
1220	2228.0	2229.8	2231.6	2233.4	2235.2	2237.0	2238.8	2240.6	2242.4	2244.2
1230	2246.0	2247.8	2249.6	2251.4	2253.2	2255.0	2256.8	2258.6	2260.4	2262.2
1240	2264.0	2265.8	2267.6	2269.4	2271.2	2273.0	2274.8	2276.6	2278.4	2280.2
1250	2282.0	2283.8	2285.6	2287.4	2289.2	2291.0	2292.8	2294.6	2296.4	2298.2
1260	2300.0	2301.8	2303.6	2305.4	2307.2	2309.0	2310.8	2312.6	2314.4	2316.2
1270	2318.0	2319.8	2321.6	2323.4	2325.2	2327.0	2328.8	2330.6	2332.4	2334.2
1280	2336.0	2337.8	2339.6	2341.4	2343.2	2345.0	2346.8	2348.6	2350.4	2352.2
1290	2354.0	2355.8	2357.6	2359.4	2361.2	2363.0	2364.8	2366.6	2368.4	2370.2
1300	2372.0	2373.8	2375.6	2377.4	2379.2	2381.0	2382.8	2384.6	2386.4	2388.2
1310	2390.0	2391.8	2393.6	2395.4	2397.2	2399.0	2400.8	2402.6	2404.4	2406.2
1320	2408.0	2409.8	2411.6	2413.4	2415.2	2417.0	2418.8	2420.6	2422.4	2424.2
1330	2426.0	2427.8	2429.6	2431.4	2433.2	2435.0	2436.8	2438.6	2440.4	2442.2
1340	2444.0	2445.8	2447.6	2449.4	2451.2	2453.0	2454.8	2456.6	2458.4	2460.2
1350	2462.0	2463.8	2465.6	2467.4	2469.2	2471.0	2472.8	2474.6	2476.4	2478.2
1360	2480.0	2481.8	2483.6	2485.4	2487.2	2489.0	2490.8	2492.6	2494.4	2496.2
1370	2498.0	2499.8	2501.6	2503.4	2505.2	2507.0	2508.8	2510.6	2512.4	2514.2
1380	2516.0	2517.8	2519.6	2521.4	2523.2	2525.0	2526.8	2528.6	2530.4	2532.2
1390	2534.0	2535.8	2537.6	2539.4	2541.2	2543.0	2544.8	2546.6	2548.4	2550.2
1400	2552.0	2553.8	2555.6	2557.4	2559.2	2561.0	2562.8	2564.6	2566.4	2568.2
1410	2570.0	2571.8	2573.6	2575.4	2577.2	2579.0	2580.8	2582.6	2584.4	2586.2
1420	2588.0	2589.8	2591.6	2593.4	2595.2	2597.0	2598.8	2600.6	2602.4	2604.2
1430	2606.0	2607.8	2609.6	2611.4	2613.2	2615.0	2616.8	2618.6	2620.4	2622.2
1440	2624.0	2625.8	2627.6	2629.4	2631.2	2633.0	2634.8	2636.6	2638.4	2640.2
1450	2642.0	2643.8	2645.6	2647.4	2649.2	2651.0	2652.8	2654.6	2656.4	2658.2
1460	2660.0	2661.8	2663.6	2665.4	2667.2	2669.0	2670.8	2672.6	2674.4	2676.2
1470	2678.0	2679.8	2681.6	2683.4	2685.2	2687.0	2688.8	2690.6	2692.4	2694.2
1480	2696.0	2697.8	2699.6	2701.4	2703.2	2705.0	2706.8	2708.6	2710.4	2712.2
1490	2714.0	2715.8	2717.6	2719.4	2721.2	2723.0	2724.8	2726.6	2728.4	2730.2
1500	2732.0	2733.8	2735.6	2737.4	2739.2	2741.0	2742.8	2744.6	2746.4	2748.2
1510	2750.0	2751.8	2753.6	2755.4	2757.2	2759.0	2760.8	2762.6	2764.4	2766.2
1520	2768.0	2769.8	2771.6	2773.4	2775.2	2777.0	2778.8	2780.6	2782.4	2784.2
1530	2786.0	2787.8	2789.6	2791.4	2793.2	2795.0	2796.8	2798.6	2800.4	2802.2
1540	2804.0	2805.8	2807.6	2809.4	2811.2	2813.0	2814.8	2816.6	2818.4	2820.2
1550	2822.0	2823.8	2825.6	2827.4	2829.2	2831.0	2832.8	2834.6	2836.4	2838.2
1560	2840.0	2841.8	2843.6	2845.4	2847.2	2849.0	2850.8	2852.6	2854.4	2856.2
1570	2858.0	2859.8	2861.6	2863.4	2865.2	2867.0	2868.8	2870.6	2872.4	2874.2
1580	2876.0	2877.8	2879.6	2881.4	2883.2	2885.0	2886.8	2888.6	2890.4	2892.2
1590	2894.0	2895.8	2897.6	2899.4	2901.2	2903.0	2904.8	2906.6	2908.4	2910.2
1600	2912.0	2913.8	2915.6	2917.4	2919.2	2921.0	2922.8	2924.6	2926.4	2928.2
1610	2930.0	2931.8	2933.6	2935.4	2937.2	2939.0	2940.8	2942.6	2944.4	2946.2
1620	2948.0	2949.8	2951.6	2953.4	2955.2	2957.0	2958.8	2960.6	2962.4	2964.2
1630	2966.0	2967.8	2969.6	2971.4	2973.2	2975.0	2976.8	2978.6	2980.4	2982.2
1640	2984.0	2985.8	2987.6	2989.4	2991.2	2993.0	2994.8	2996.6	2998.4	3000.2
1650	3002.0	3003.8	3005.6	3007.4	3009.2	3011.0	3012.8	3014.6	3016.4	3018.2
1660	3020.0	3021.8	3023.6	3025.4	3027.2	3029.0	3030.8	3032.6	3034.4	3036.2
1670	3038.0	3039.8	3041.6	3043.4	3045.2	3047.0	3048.8	3050.6	3052.4	3054.2
1680	3056.0	3057.8	3059.6	3061.4	3063.2	3065.0	3066.8	3068.6	3070.4	3072.2
1690	3074.0	3075.8	3077.6	3079.4	3081.2	3083.0	3084.8	3086.6	3088.4	3090.2
1700	3092.0	3093.8	3095.6	3097.4	3099.2	3101.0	3102.8	3104.6	3106.4	3108.2
1710	3110.0	3111.8	3113.6	3115.4	3117.2	3119.0	3120.8	3122.6	3124.4	3126.2
1720	3128.0	3129.8	3131.6	3133.4	3135.2	3137.0	3138.8	3140.6	3142.4	3144.2
1730	3146.0	3147.8	3149.6	3151.4	3153.2	3155.0	3156.8	3158.6	3160.4	3162.2
1740	3164.0	3165.8	3167.6	3169.4	3171.2	3173.0	3174.8	3176.6	3178.4	3180.2
1750	3182.0	3183.8	3185.6	3187.4	3189.2	3191.0	3192.8	3194.6	3196.4	3198.2
1760	3200.0	3201.8	3203.6	3205.4	3207.2	3209.0	3210.8	3212.6	3214.4	3216.2
1770	3218.0	3219.8	3221.6	3223.4	3225.2	3227.0	3228.8	3230.6	3232.4	3234.2
1780	3236.0	3237.8	3239.6	3241.4	3243.2	3245.0	3246.8	3248.6	3250.4	3252.2
1790	3254.0	3255.8	3257.6	3259.4	3261.2	3263.0	3264.8	3266.6	3268.4	3270.2

Copper-Constantan Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F.

TYPE C. C.

Deg. Fahr.	-200	-100	-0	+0	+100	+200	+300	+400	+500	Deg. Fahr.
MILLIVOLTS										
0	-4.11	-2.56	-0.671	-0.671	1.52	3.97	6.64	9.52	12.57	0
5	-4.18	-2.65	-0.773	-0.568	1.63	4.09	6.78	9.67	12.73	5
10	-4.25	-2.73	-0.874	-0.465	1.75	4.22	6.92	9.82	12.88	10
15	-4.31	-2.82	-0.975	-0.360	1.87	4.35	7.06	9.97	13.04	15
20	-4.38	-2.90	-1.07	-0.255	1.99	4.48	7.21	10.12	13.20	20
25	-4.43	-2.98	-1.17	-0.149	2.11	4.61	7.35	10.27	13.36	25
30	-4.50	-3.06	-1.27	-0.043	2.23	4.75	7.49	10.42	13.52	30
35	-4.57	-3.14	-1.37	0.064	2.35	4.88	7.63	10.57	13.67	35
40	-4.63	-3.22	-1.47	0.172	2.47	5.01	7.77	10.72	13.83	40
45	-4.69	-3.30	-1.56	0.281	2.59	5.15	7.92	10.87	13.99	45
50	-4.75	-3.38	-1.66	0.389	2.71	5.28	8.06	11.03	14.15	50
55	-4.80	-3.46	-1.75	0.499	2.83	5.41	8.20	11.18	14.31	55
60	-4.86	-3.53	-1.84	0.609	2.96	5.55	8.35	11.33	14.47	60
65	-4.92	-3.61	-1.94	0.720	3.08	5.68	8.49	11.49	14.63	65
70	-4.97	-3.68	-2.03	0.832	3.21	5.82	8.64	11.64	14.79	70
75	-5.03	-3.76	-2.12	0.944	3.33	5.96	8.79	11.79	14.96	75
80	-5.08	-3.83	-2.21	1.06	3.46	6.09	8.93	11.95	15.12	80
85	-5.13	-3.90	-2.30	1.17	3.58	6.23	9.08	12.10	15.28	85
90	-5.18	-3.97	-2.39	1.29	3.71	6.37	9.23	12.26	15.44	90
95	-5.23	-4.04	-2.47	1.40	3.84	6.51	9.37	12.41	15.61	95
100	-5.28	-4.11	-2.56	1.52	3.97	6.64	9.52	12.57	15.77	100
M. V. per °F.	0.0117	0.0155	0.0189	0.0219	0.0245	0.0268	0.0287	0.0305	0.0320	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $-248^{\circ} = -(245^{\circ} + 3^{\circ}) = -(4.69 + 3 \times 0.0117) \text{ m. v.} = -4.725 \text{ m. v.}$
(Negative Degrees)

Example: $472^{\circ} = 470^{\circ} + 2^{\circ} = 11.64 \text{ m. v.} + (2 \times 0.0305) \text{ m. v.} = 11.701 \text{ m. v.}$
(Positive Degrees)

Copper-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT
TYPE C. C.

COLD JUNCTION 32° F.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Fahr. per 0.01 M.V.
DEGREES FAHRENHEIT													
-5	-273	-282	-292	-302	-312	-323	-335	-348	-363	-378	-394	-5	1.21
-4	-192	-199	-207	-214	-222	-230	-238	-246	-255	-263	-273	-4	.81
-3	-127	-132	-138	-145	-151	-158	-164	-171	-178	-185	-192	-3	.66
-2	-68	-74	-79	-85	-91	-97	-102	-108	-114	-120	-127	-2	.59
-1	-17	-22	-27	-32	-37	-42	-47	-52	-58	-63	-68	-1	.51
-0	32	27	22	18	13	8	3	-2	-7	-12	-17	-0	.49
+0	32	37	42	46	51	55	60	64	68	73	78	+0	.46
1	78	82	86	91	95	99	103	108	112	116	121	1	.43
2	121	125	129	133	137	141	145	150	154	158	162	2	.41
3	162	166	170	174	178	182	186	190	194	198	201	3	.39
4	201	205	209	213	217	221	225	228	232	236	240	4	.38
5	240	243	247	251	254	258	262	265	269	273	276	5	.37
6	276	280	284	287	291	295	298	302	306	309	313	6	.37
7	313	316	320	323	327	330	334	337	341	345	348	7	.35
8	348	352	355	358	362	365	369	372	376	379	383	8	.35
9	383	386	389	392	396	399	403	406	409	413	416	9	.33
10	416	419	423	426	429	433	436	439	443	446	449	10	.33
11	449	452	456	459	462	465	469	472	475	478	482	11	.32
12	482	485	488	491	494	498	501	504	507	510	513	12	.31
13	513	517	520	523	526	529	533	536	539	542	545	13	.32
14	545	548	552	555	558	561	564	567	570	573	576	14	.31
15	576	579	582	586	589	592	595	598	601	604	607	15	.31

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right hand column) for each 0.01 m.v. above the lower printed value.

Example: $-3.54 \text{ m. v.} = -(3.50 + 0.04) \text{ m. v.}$
 (Negative m. v.) $0.04 \text{ m. v.} = \frac{0.04}{0.01} \times 0.66^\circ = 2.64^\circ \text{ F.}$
 $-3.50 \text{ m. v.} = -158^\circ \text{ F.}$
 $-3.54 \text{ m. v.} = -(158^\circ + 2.64^\circ) = -160.64^\circ \text{ F.}$

Example: $12.25 \text{ m. v.} = 12.20 \text{ m. v.} + 0.05 \text{ m. v.}$
 (Positive m. v.) $0.05 \text{ m. v.} = \frac{0.05}{0.01} \times 0.31^\circ = 1.55^\circ \text{ F.}$
 $12.20 \text{ m. v.} = 488^\circ \text{ F.}$
 $12.25 \text{ m. v.} = 488^\circ + 1.55^\circ = 489.55^\circ \text{ F.}$

Special (B. S.) Iron-Constantan Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F.

TYPE B. S.

Do not confuse with I. C. Thermocouple

Deg. Fahr.	-200	-100	-0	0	100	200	300	400	500	600	700	Deg. Fahr.
MILLIVOLTS												
0	-6.01	-3.63	-0.918	-0.918	2.00	5.03	8.12	11.24	14.35	17.43	20.48	0
5	-6.12	-3.76	-1.06	-0.778	2.15	5.18	8.28	11.40	14.50	17.58	20.64	5
10	-6.23	-3.88	-1.20	-0.633	2.30	5.34	8.44	11.56	14.65	17.73	20.79	10
15	-6.33	-4.01	-1.34	-0.490	2.45	5.49	8.59	11.71	14.81	17.88	20.94	15
20	-6.43	-4.14	-1.48	-0.346	2.60	5.64	8.75	11.87	14.96	18.04	21.09	20
25	-6.54	-4.26	-1.62	-0.202	2.75	5.80	8.90	12.02	15.12	18.19	21.25	25
30	-6.64	-4.39	-1.76	-0.058	2.90	5.95	9.06	12.18	15.27	18.34	21.40	30
35	-6.73	-4.51	-1.90	0.087	3.05	6.11	9.22	12.33	15.43	18.50	21.55	35
40	-6.83	-4.63	-2.04	0.232	3.20	6.26	9.37	12.49	15.58	18.65	21.70	40
45	-6.93	-4.75	-2.17	0.378	3.35	6.42	9.53	12.64	15.73	18.80	21.86	45
50	-7.02	-4.87	-2.31	0.524	3.50	6.57	9.68	12.80	15.89	18.95	22.01	50
55	-7.11	-4.99	-2.44	0.671	3.65	6.73	9.84	12.96	16.04	19.11	22.16	55
60	-7.21	-5.11	-2.58	0.817	3.81	6.88	10.00	13.11	16.20	19.26	22.31	60
65	-7.29	-5.22	-2.71	0.961	3.96	7.04	10.15	13.26	16.35	19.41	22.47	65
70	-7.38	-5.34	-2.85	1.11	4.11	7.19	10.31	13.42	16.50	19.57	22.62	70
75	-7.47	-5.45	-2.98	1.26	4.26	7.35	10.46	13.57	16.66	19.72	22.77	75
80	-7.55	-5.57	-3.11	1.41	4.42	7.50	10.62	13.73	16.81	19.87	22.92	80
85	-7.63	-5.68	-3.24	1.56	4.57	7.66	10.78	13.88	16.97	20.02	23.08	85
90	-7.72	-5.79	-3.37	1.70	4.72	7.81	10.93	14.04	17.12	20.18	23.23	90
95	-7.79	-5.90	-3.50	1.85	4.87	7.97	11.09	14.19	17.27	20.33	23.38	95
100	-7.87	-6.01	-3.63	2.00	5.03	8.12	11.24	14.35	17.43	20.48	23.53	100
M. V. per °F.	0.0186	0.0235	0.0271	0.0292	0.0303	0.0310	0.0312	0.0310	0.0308	0.0305	0.0305	M. V. per °F.

Deg. Fahr.	800	900	1000	1100	1200	1300	1400	1500	1600	1700	Deg. Fahr.
	MILLIVOLTS										
0	23.53	26.59	29.70	32.88	36.17	39.58	43.12	46.74	50.39	53.87	0
5	23.69	26.75	29.86	33.04	36.34	39.75	43.30	46.92	50.57	54.03	5
10	23.84	26.90	30.01	33.21	36.50	39.93	43.48	47.10	50.76	54.20	10
15	23.99	27.06	30.17	33.37	36.67	40.10	43.66	47.29	50.94	54.36	15
20	24.14	27.21	30.33	33.53	36.84	40.28	43.84	47.47	51.12	54.52	20
25	24.30	27.36	30.49	33.69	37.01	40.45	44.02	47.65	51.31	54.69	25
30	24.45	27.52	30.65	33.86	37.18	40.63	44.20	47.84	51.49	54.85	30
35	24.60	27.67	30.80	34.02	37.35	40.81	44.38	48.02	51.67	55.02	35
40	24.75	27.83	30.96	34.18	37.52	40.98	44.56	48.20	51.86	55.18	40
45	24.91	27.98	31.12	34.35	37.69	41.16	44.74	48.38	52.04	55.35	45
50	25.06	28.14	31.28	34.51	37.86	41.34	44.93	48.57	52.22	55.51	50
55	25.21	28.29	31.44	34.68	38.03	41.52	45.11	48.75	52.39	55.57	55
60	25.37	28.45	31.60	34.84	38.20	41.69	45.29	48.93	52.55	55.84	60
65	25.52	28.61	31.76	35.01	38.37	41.87	45.47	49.11	52.71	56.01	65
70	25.67	28.76	31.92	35.17	38.54	42.05	45.65	49.30	52.88	56.17	70
75	25.83	28.92	32.08	35.34	38.71	42.23	45.83	49.48	53.04	56.34	75
80	25.98	29.07	32.24	35.50	38.89	42.41	46.01	49.66	53.21	56.50	80
85	26.13	29.23	32.40	35.67	39.06	42.58	46.19	49.84	53.37	56.67	85
90	26.29	29.39	32.56	35.84	39.23	42.76	46.38	50.03	53.54	56.83	90
95	26.44	29.54	32.72	36.00	39.37	42.94	46.56	50.21	53.70	57.00	95
100	26.59	29.70	32.88	36.17	39.58	43.12	46.74	50.39	53.87	57.16	100
M. V. per °F.	0.0306	0.0311	0.0318	0.0329	0.0341	0.0355	0.0362	0.0365	0.0347	0.0329	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $-149^{\circ} = -(145^{\circ} + 4^{\circ}) = -(4.75 + 4 \times 0.0235) \text{ m. v.} = -4.844 \text{ m. v.}$
(Negative Degrees)

Example: $1452^{\circ} = 1450^{\circ} + 2^{\circ} = 44.93 \text{ m. v.} + (2 \times 0.0362) \text{ m. v.} = 45.00 \text{ m. v.}$
(Positive Degrees)

Special (B. S.) Iron-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT

COLD JUNCTION 32° F.

TYPE B. S.

Do not confuse with I. C. Thermocouple

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Fahr. per 0.01 M.V.
DEGREES FAHRENHEIT													
-7	-249	-254	-259	-265	-271	-277	-283	-289	-295	-302	-308	-7	.59
-6	-200	-204	-209	-214	-219	-223	-228	-233	-238	-243	-249	-6	.49
-5	-156	-160	-164	-168	-173	-177	-182	-186	-190	-195	-200	-5	.44
-4	-114	-118	-122	-126	-131	-135	-139	-143	-147	-151	-156	-4	.42
-3	-76	-80	-83	-87	-91	-95	-99	-103	-107	-111	-114	-3	.38
-2	-39	-42	-46	-49	-53	-57	-61	-64	-68	-72	-76	-2	.37
-1	-3	-7	-10	-14	-17	-21	-24	-28	-31	-35	-39	-1	.36
-0	+ 32	+ 28	+ 25	+ 21	+ 18	+ 14	+ 11	+ 7	+ 4	+ 1	- 3	-0	.35
+0	32	36	39	42	46	49	53	56	59	63	66	+0	.34
1	66	70	73	76	80	83	86	90	93	97	100	1	.34
2	100	103	107	110	113	117	120	123	127	130	133	2	.33
3	133	137	140	143	147	150	153	157	160	163	166	3	.33
4	166	170	173	176	179	183	186	189	193	196	199	4	.33
5	199	202	206	209	212	215	218	222	225	228	231	5	.32
6	231	234	238	241	244	247	251	254	257	260	264	6	.33
7	264	267	270	274	277	280	283	286	290	293	296	7	.32
8	296	299	303	306	309	312	315	319	322	325	328	8	.32
9	328	331	334	338	341	344	347	350	353	357	360	9	.32
10	360	363	366	370	373	376	379	382	386	389	392	10	.32
11	392	395	398	402	405	408	411	415	418	421	424	11	.32
12	424	427	431	434	437	440	443	447	450	453	456	12	.32
13	456	460	463	466	469	472	475	479	482	485	488	13	.32
14	488	492	495	498	502	505	508	511	515	518	521	14	.32
15	521	524	528	531	534	537	541	544	547	550	554	15	.33
16	554	557	560	563	567	570	573	576	580	583	586	16	.32
17	586	589	593	596	599	602	606	609	612	616	619	17	.33
18	619	622	625	629	632	635	638	642	645	648	651	18	.32
19	651	654	658	661	664	668	671	674	678	681	684	19	.33
20	684	687	691	694	697	701	704	707	711	714	717	20	.33
21	717	720	724	727	730	734	737	740	743	747	750	21	.33
22	750	753	757	760	763	766	770	773	776	779	783	22	.33
23	783	786	789	792	796	799	802	805	809	812	815	23	.32
24	815	819	822	825	828	832	835	838	842	845	848	24	.33
25	848	851	855	858	861	864	868	871	874	877	881	25	.33
26	881	884	887	890	894	897	900	904	907	910	913	26	.32
27	913	916	919	923	926	929	932	936	939	942	945	27	.32
28	945	948	952	955	958	961	965	968	971	974	977	28	.32
29	977	981	984	987	990	993	997	1000	1003	1006	1009	29	.32
30	1009	1013	1016	1019	1022	1025	1029	1032	1035	1038	1041	30	.32
31	1041	1044	1048	1051	1054	1057	1060	1063	1066	1069	1073	31	.32
32	1073	1076	1079	1082	1085	1088	1091	1094	1097	1100	1103	32	.31
33	1103	1107	1110	1113	1116	1119	1122	1125	1128	1131	1134	33	.31
34	1134	1137	1141	1144	1147	1150	1153	1156	1159	1162	1165	34	.31
35	1165	1168	1171	1174	1177	1180	1183	1186	1189	1192	1195	35	.30
36	1195	1198	1201	1204	1207	1210	1213	1216	1219	1222	1225	36	.30
37	1225	1228	1231	1233	1236	1239	1242	1245	1248	1251	1254	37	.30
38	1254	1257	1260	1263	1266	1269	1272	1274	1277	1280	1283	38	.29
39	1283	1286	1289	1292	1295	1298	1301	1304	1306	1309	1312	39	.29
40	1312	1315	1318	1321	1323	1326	1329	1332	1335	1338	1341	40	.29
41	1341	1343	1346	1349	1352	1355	1358	1360	1363	1366	1369	41	.28
42	1369	1371	1374	1377	1380	1382	1385	1388	1391	1394	1397	42	.28
43	1397	1400	1402	1405	1408	1411	1413	1416	1419	1422	1424	43	.28
44	1424	1427	1430	1433	1435	1438	1441	1444	1447	1449	1452	44	.29
45	1452	1455	1458	1460	1463	1466	1469	1471	1474	1477	1480	45	.28
46	1480	1482	1485	1488	1491	1493	1496	1499	1502	1504	1507	46	.28
47	1507	1510	1513	1515	1518	1521	1524	1526	1529	1532	1535	47	.28
48	1535	1537	1540	1543	1546	1548	1551	1554	1556	1559	1562	48	.27
49	1562	1565	1567	1570	1573	1576	1578	1581	1584	1587	1589	49	.27
50	1589	1592	1595	1597	1600	1603	1606	1608	1611	1614	1617	50	.28
51	1617	1619	1622	1625	1628	1630	1633	1636	1638	1641	1644	51	.29
52	1644	1646	1649	1652	1655	1658	1661	1664	1667	1670	1673	52	.29
53	1673	1676	1679	1682	1686	1689	1692	1695	1698	1701	1704	53	.31
54	1704	1707	1710	1713	1716	1719	1722	1725	1728	1731	1734	54	.30
55	1734	1737	1741	1744	1747	1750	1753	1756	1759	1762	1765	55	.31
56	1765	1768	1771	1774	1777	1780	1783	1786	1789	1792	1795	56	.31
57	1795	1798	1801	1804	1808	1811	1814	1817	1820	1823	1826	57	.31

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right hand column) for each 0.01 m.v. above the lower printed value.

Example: - 6.23 m. v. = - (6.20 + 0.03) m. v.
(Negative m. v.) $0.03 \text{ m. v.} = \frac{0.03}{0.01} \times 0.49^\circ = 1.47^\circ \text{ F.}$
- 6.20 m. v. = - 209° F.
- 6.23 m. v. = - (209° + 1.47°) = - 210.47° F.

Example: 40.66 m. v. = 40.60 m. v. + 0.06 m. v.
(Positive m. v.) $0.06 \text{ m. v.} = \frac{0.06}{0.01} \times 0.28^\circ = 1.74^\circ \text{ F.}$
40.60 m. v. = 1329° F.
40.66 m. v. = 1329° + 1.74° = 1330.74° F.

Iron-Constantan Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F

TYPE I. C.

Deg. Fahr.	0	100	200	300	400	500	600	700	800	900	1000	Deg. Fahr.
MILLIVOLTS												
0	-0.922	1.96	4.92	7.95	11.02	14.09	17.16	20.23	23.31	26.41*	29.54	0
5	-0.778	2.11	5.07	8.10	11.18	14.24	17.31	20.38	23.46	26.57	29.70	5
10	-0.634	2.26	5.22	8.26	11.32	14.40	17.47	20.54	23.62	26.72	29.86	10
15	-0.490	2.40	5.37	8.41	11.48	14.55	17.62	20.69	23.77	26.88	30.02	15
20	-0.346	2.55	5.53	8.56	11.63	14.70	17.77	20.85	23.93	27.04	30.18	20
25	-0.202	2.70	5.68	8.72	11.79	14.86	17.93	21.00	24.08	27.19	30.34	25
30	-0.058	2.85	5.83	8.87	11.94	15.01	18.08	21.15	24.24	27.35	30.50	30
35	0.088	3.00	5.98	9.02	12.09	15.16	18.23	21.31	24.39	27.50	30.66	35
40	0.228	3.14	6.13	9.18	12.25	15.32	18.39	21.46	24.55	27.66	30.82	40
45	0.378	3.29	6.28	9.33	12.40	15.47	18.54	21.62	24.70	27.82	30.98	45
50	0.518	3.44	6.44	9.48	12.55	15.62	18.69	21.77	24.86	27.97	31.14	50
55	0.658	3.59	6.58	9.64	12.71	15.78	18.85	21.92	25.01	28.13	31.30	55
60	0.808	3.74	6.74	9.79	12.86	15.93	19.00	22.08	25.17	28.29	31.46	60
65	0.948	3.88	6.89	9.94	13.02	16.08	19.15	22.23	25.32	28.44	31.62	65
70	1.10	4.03	7.04	10.10	13.17	16.24	19.31	22.39	25.48	28.60	31.78	70
75	1.24	4.18	7.19	10.25	13.32	16.39	19.46	22.54	25.63	28.76	31.94	75
80	1.38	4.33	7.34	10.40	13.48	16.55	19.62	22.69	25.79	28.91	32.10	80
85	1.53	4.48	7.50	10.55	13.63	16.70	19.77	22.85	25.94	29.07	32.26	85
90	1.67	4.62	7.65	10.71	13.78	16.85	19.92	23.00	26.10	29.23	32.42	90
95	1.82	4.77	7.80	10.86	13.94	17.01	20.08	23.16	26.25	29.38	32.58	95
100	1.96	4.92	7.95	11.02	14.03	17.16	20.23	23.31	26.41	29.54	32.74	100
M. V. per °F.	0.0288	0.0296	0.0303	0.0307	0.0307	0.0307	0.0307	0.0308	0.0310	0.0313	0.0320	M. V. per °F.

Deg. Fahr.	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	Deg. Fahr.
MILLIVOLTS												
0	32.74	36.04	39.46	42.96	46.48	50.00	53.52	57.04	60.56	64.08	67.60	0
5	32.90	36.21	39.64	43.14	46.66	50.18	53.70	57.22	60.74	64.26	67.78	5
10	33.07	36.38	39.81	43.31	46.83	50.35	53.87	57.39	60.91	64.43	67.95	10
15	33.23	36.55	39.98	43.49	47.01	50.53	54.05	57.57	61.09	64.61	68.13	15
20	33.40	36.72	40.16	43.66	47.18	50.70	54.22	57.74	61.26	64.78	68.30	20
25	33.56	36.89	40.34	43.84	47.36	50.88	54.40	57.92	61.44	64.96	68.48	25
30	33.73	37.07	40.51	44.02	47.54	51.06	54.58	58.10	61.62	65.14	68.66	30
35	33.89	37.24	40.68	44.19	47.71	51.23	54.75	58.27	61.79	65.31	68.83	35
40	34.06	37.41	40.86	44.37	47.89	51.41	54.93	58.45	61.97	65.49	69.01	40
45	34.22	37.58	41.03	44.54	48.06	51.58	55.10	58.62	62.14	65.66	69.18	45
50	34.39	37.75	41.21	44.72	48.24	51.76	55.28	58.80	62.32	65.84	69.36	50
55	34.55	37.92	41.38	44.90	48.42	51.94	55.46	58.98	62.50	66.02	69.54	55
60	34.72	38.09	41.56	45.07	48.59	52.11	55.63	59.15	62.67	66.19	69.71	60
65	34.88	38.26	41.73	45.25	48.77	52.29	55.81	59.33	62.85	66.37	69.89	65
70	35.05	38.43	41.91	45.42	48.94	52.46	55.98	59.50	63.02	66.54	70.06	70
75	35.21	38.60	42.08	45.60	49.12	52.64	56.16	59.68	63.20	66.72	70.24	75
80	35.38	38.78	42.26	45.78	49.30	52.82	56.34	59.86	63.38	66.90	70.42	80
85	35.54	38.95	42.43	45.95	49.47	52.99	56.51	60.03	63.55	67.07	70.59	85
90	35.71	39.12	42.61	46.13	49.65	53.17	56.69	60.21	63.73	67.25	70.77	90
95	35.87	39.29	42.78	46.30	49.82	53.34	56.86	60.38	63.90	67.42	70.94	95
100	36.04	39.46	42.96	46.48	50.00	53.52	57.04	60.56	64.08	67.60	71.12	100
M. V. per °F.	0.0330	0.0342	0.0350	0.0352	0.0352	0.0352	0.0352	0.0352	0.0352	0.0352	0.0352	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $1452^{\circ} = 1450^{\circ} + 2^{\circ} = 44.72 \text{ m. v.} + (2 \times .0352) = 44.79 \text{ m. v.}$
 $78^{\circ} = 75^{\circ} + 3^{\circ} = 1.24 \text{ m. v.} + (3 \times .0288) = 1.326 \text{ m. v.}$

Iron-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT

COLD JUNCTION 32° F.

TYPE I. C.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Fahr. per 0.01 M.V.
DEGREES FAHRENHEIT													
0	32	36	39	43	46	49	53	56	60	63	67	0	.35
1	67	70	74	77	81	84	88	91	95	98	102	1	.35
2	102	105	108	111	115	118	122	125	129	132	135	2	.33
3	135	138	142	145	149	152	156	159	162	165	169	3	.34
4	169	172	176	179	183	186	190	193	196	199	203	4	.34
5	203	206	210	213	217	220	223	226	230	233	236	5	.33
6	236	239	243	246	250	253	256	259	263	266	269	6	.33
7	269	272	276	279	283	286	289	292	296	299	302	7	.33
8	302	305	309	312	315	318	322	325	328	331	335	8	.33
9	335	338	341	344	348	351	354	357	361	364	368	9	.33
10	368	371	374	377	380	383	387	390	393	396	400	10	.32
11	400	403	406	409	413	416	419	422	426	429	432	11	.32
12	432	435	439	442	445	448	452	455	458	461	465	12	.32
13	465	468	471	474	478	481	484	487	491	494	497	13	.32
14	497	500	504	507	510	513	517	520	523	526	530	14	.33
15	530	533	536	539	543	546	549	552	556	559	562	15	.32
16	562	565	569	572	576	579	582	585	589	592	595	16	.33
17	595	598	602	605	609	612	615	618	622	625	628	17	.33
18	628	631	635	638	641	644	648	651	654	657	661	18	.33
19	661	664	667	670	673	676	680	683	686	689	693	19	.32
20	693	696	699	702	706	709	712	715	719	722	725	20	.32
21	725	728	732	735	738	741	745	748	751	754	758	21	.33
22	758	761	764	767	771	774	777	780	784	787	790	22	.32
23	790	793	797	800	803	806	810	813	816	819	823	23	.33
24	823	826	829	832	835	838	842	845	848	851	855	24	.32
25	855	858	861	864	868	871	874	877	881	884	887	25	.32
26	887	890	894	897	900	903	907	910	913	916	920	26	.33
27	920	923	926	929	932	935	939	942	945	948	952	27	.32
28	952	955	958	961	964	967	970	973	977	980	983	28	.31
29	983	986	989	992	995	998	1002	1005	1008	1011	1015	29	.32
30	1015	1018	1021	1024	1027	1030	1033	1036	1040	1043	1046	30	.31
31	1046	1049	1052	1055	1058	1061	1064	1067	1071	1074	1077	31	.31
32	1077	1080	1084	1087	1090	1093	1096	1099	1102	1105	1108	32	.31
33	1108	1111	1114	1117	1120	1123	1126	1129	1133	1136	1139	33	.31
34	1139	1142	1145	1148	1151	1154	1157	1160	1163	1166	1169	34	.30
35	1169	1172	1175	1178	1181	1184	1187	1190	1193	1196	1199	35	.30
36	1199	1202	1205	1208	1211	1214	1217	1219	1222	1225	1228	36	.29
37	1228	1231	1234	1237	1240	1243	1246	1249	1252	1254	1257	37	.29
38	1257	1260	1263	1266	1269	1272	1275	1278	1281	1283	1286	38	.29
39	1286	1289	1292	1295	1298	1301	1304	1307	1310	1312	1315	39	.29
40	1315	1318	1321	1324	1327	1330	1333	1336	1339	1341	1344	40	.29
41	1344	1347	1350	1353	1356	1359	1362	1365	1368	1370	1373	41	.29
42	1373	1376	1379	1382	1385	1388	1391	1394	1397	1399	1402	42	.29
43	1402	1405	1408	1411	1414	1417	1420	1422	1425	1428	1431	43	.29
44	1431	1433	1436	1439	1442	1445	1448	1450	1453	1456	1459	44	.28
45	1459	1461	1464	1467	1470	1473	1476	1479	1482	1484	1487	45	.28
46	1487	1490	1493	1496	1499	1502	1505	1507	1510	1513	1516	46	.29
47	1516	1518	1521	1524	1527	1530	1533	1535	1538	1541	1544	47	.28
48	1544	1546	1549	1552	1555	1558	1561	1563	1566	1569	1572	48	.28
49	1572	1574	1577	1580	1583	1586	1589	1592	1595	1597	1600	49	.28
50	1600	1603	1606	1609	1612	1615	1618	1620	1623	1626	1629	50	.29
51	1629	1631	1634	1637	1640	1643	1646	1649	1652	1654	1657	51	.28
52	1657	1660	1663	1666	1669	1672	1675	1677	1680	1683	1686	52	.29
53	1686	1688	1691	1694	1697	1700	1703	1706	1709	1711	1714	53	.28
54	1714	1717	1720	1723	1726	1729	1732	1734	1737	1740	1743	54	.29
55	1743	1745	1748	1751	1754	1757	1760	1762	1765	1768	1771	55	.28
56	1771	1773	1776	1779	1782	1785	1788	1791	1794	1796	1799	56	.28
57	1799	1802	1805	1808	1811	1814	1817	1819	1822	1825	1828	57	.29
58	1828	1830	1833	1836	1839	1842	1845	1848	1851	1853	1856	58	.28
59	1856	1859	1862	1865	1868	1871	1874	1876	1879	1882	1885	59	.29
60	1885	1887	1890	1893	1896	1899	1902	1905	1908	1910	1913	60	.28
61	1913	1916	1919	1922	1925	1928	1931	1933	1936	1939	1942	61	.29
62	1942	1944	1947	1950	1953	1956	1959	1961	1964	1967	1970	62	.28
63	1970	1972	1975	1978	1981	1984	1987	1989	1992	1995	1998	63	.28
64	1998	2000	2003	2006	2009	2012	2015	2018	2021	2023	2026	64	.28
65	2026	2029	2032	2035	2037	2040	2043	2046	2049	2052	2054	65	.28
66	2054	2057	2060	2063	2066	2069	2072	2075	2077	2080	2083	66	.29
67	2083	2086	2089	2092	2095	2097	2100	2103	2105	2108	2111	67	.28
68	2111	2114	2117	2120	2123	2125	2128	2131	2134	2137	2140	68	.29
69	2140	2143	2146	2149	2151	2154	2157	2160	2163	2165	2168	69	.28
70	2168	2171	2174	2177	2179	2182	2185	2188	2191	2194	2197	70	.29

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right-hand column) for each 0.01 m.v. above the lower printed value.

Example. 40.66 m. v. 40.60 m. v. + .06 m. v.

.06 m. v. .29 1.74

40.60 m. v. 1333 F. 40.66 m. v. + .06 m. v. 1333 + 1.74 1334.74 F.

THE BROWN INSTRUMENT CO.

PHILADELPHIA, PA., U. S. A.

Chromel-Alumel Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F.

TYPE M. A.

Deg. F.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	Deg. F.
MILLIVOLTS														
0	-0.68	1.52	3.82	6.09	8.31	10.56	12.85	15.18	17.52	19.88	22.25	24.62	26.98	0
5	-0.58	1.63	3.93	6.20	8.42	10.67	12.96	15.29	17.63	20.00	22.37	24.74	27.10	5
10	-0.47	1.74	4.05	6.31	8.53	10.79	13.08	15.41	17.75	20.12	22.49	24.85	27.21	10
15	-0.37	1.85	4.16	6.42	8.64	10.90	13.19	15.52	17.87	20.24	22.60	24.97	27.33	15
20	-0.26	1.97	4.28	6.53	8.76	11.02	13.31	15.64	17.99	20.36	22.72	25.09	27.45	20
25	-0.15	2.08	4.39	6.64	8.87	11.13	13.43	15.76	18.10	20.47	22.84	25.21	27.57	25
30	-0.04	2.20	4.51	6.75	8.98	11.25	13.55	15.88	18.22	20.59	22.96	25.33	27.68	30
35	0.07	2.31	4.62	6.86	9.09	11.36	13.67	16.00	18.34	20.71	23.08	25.45	27.80	35
40	0.18	2.43	4.74	6.98	9.20	11.47	13.78	16.11	18.46	20.83	23.20	25.57	27.92	40
45	0.29	2.54	4.85	7.09	9.31	11.58	13.89	16.23	18.58	20.95	23.32	25.69	28.04	45
50	0.40	2.66	4.97	7.20	9.43	11.70	14.01	16.35	18.70	21.07	23.43	25.80	28.15	50
55	0.51	2.77	5.08	7.31	9.55	11.81	14.12	16.47	18.81	21.18	23.55	25.92	28.27	55
60	0.62	2.89	5.19	7.42	9.66	11.93	14.24	16.58	18.93	21.30	23.67	26.04	28.39	60
65	0.73	3.00	5.30	7.53	9.77	12.04	14.36	16.70	19.05	21.42	23.79	26.16	28.51	65
70	0.84	3.12	5.42	7.64	9.88	12.16	14.48	16.82	19.17	21.54	23.91	26.27	28.62	70
75	0.95	3.24	5.53	7.75	9.99	12.27	14.60	16.93	19.29	21.66	24.02	26.39	28.74	75
80	1.06	3.36	5.64	7.87	10.11	12.39	14.71	17.05	19.41	21.78	24.14	26.51	28.86	80
85	1.17	3.48	5.75	7.98	10.22	12.50	14.83	17.17	19.52	21.89	24.26	26.63	28.98	85
90	1.29	3.59	5.87	8.09	10.33	12.62	14.94	17.29	19.64	22.01	24.38	26.74	29.09	90
95	1.40	3.70	5.98	8.20	10.44	12.73	15.06	17.40	19.76	22.13	24.50	26.86	29.21	95
100	1.52	3.82	6.09	8.31	10.56	12.85	15.18	17.52	19.88	22.25	24.62	26.98	29.33	100
M. V. per °F.	0.0220	0.0230	0.0227	0.0222	0.0225	0.0229	0.0233	0.0234	0.0236	0.0237	0.0237	0.0236	0.0235	M. V. per °F.

Deg. F.	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	Deg. F.
	MILLIVOLTS												
0	29.33	31.65	33.94	36.20	38.43	40.62	42.77	44.89	46.97	49.01	51.00	52.95	0
5	29.45	31.77	34.06	36.31	38.54	40.73	42.88	45.00	47.08	49.11	51.10	53.05	5
10	29.56	31.88	34.17	36.42	38.65	40.83	42.98	45.10	47.18	49.21	51.20	53.14	10
15	29.68	32.00	34.29	36.54	38.76	40.94	43.09	45.20	47.28	49.31	51.30	53.24	15
20	29.79	32.11	34.40	36.65	38.87	41.05	43.20	45.31	47.38	49.41	51.39	53.33	20
25	29.91	32.23	34.51	36.76	38.98	41.16	43.31	45.41	47.49	49.51	51.49	53.43	25
30	30.02	32.34	34.62	36.87	39.09	41.27	43.41	45.52	47.59	49.61	51.59	53.52	30
35	30.14	32.46	34.74	36.99	39.20	41.38	43.52	45.62	47.69	49.71	51.69	53.62	35
40	30.26	32.57	34.85	37.10	39.31	41.48	43.62	45.73	47.79	49.81	51.78	53.71	40
45	30.38	32.69	34.97	37.21	39.42	41.59	43.73	45.83	47.89	49.91	51.88	53.81	45
50	30.49	32.80	35.08	37.32	39.53	41.70	43.83	45.93	47.99	50.01	51.98	53.90	50
55	30.61	32.92	35.19	37.43	39.64	41.81	43.94	46.04	48.10	50.11	52.08	54.00	55
60	30.72	33.03	35.30	37.54	39.75	41.91	44.04	46.14	48.20	50.21	52.17	54.09	60
65	30.84	33.15	35.42	37.65	39.86	42.02	44.15	46.25	48.30	50.31	52.27	54.19	65
70	30.96	33.26	35.53	37.76	39.96	42.13	44.26	46.35	48.40	50.41	52.37	54.28	70
75	31.08	33.38	35.64	37.88	40.07	42.24	44.37	46.46	48.51	50.51	52.47	54.38	75
80	31.19	33.49	35.75	37.99	40.18	42.34	44.47	46.56	48.61	50.61	52.56	54.47	80
85	31.31	33.60	35.87	38.10	40.29	42.45	44.58	46.66	48.71	50.71	52.66	54.57	85
90	31.42	33.71	35.98	38.21	40.40	42.56	44.68	46.76	48.81	50.80	52.75	54.66	90
95	31.54	33.83	36.09	38.32	40.51	42.67	44.79	46.87	48.91	50.90	52.85	54.76	95
100	31.65	33.94	36.20	38.43	40.62	42.77	44.89	46.97	49.01	51.00	52.95	54.85	100
M. V. per °F.	0.0232	0.0229	0.0226	0.0223	0.0219	0.0215	0.0212	0.0208	0.0204	0.0199	0.0195	0.0190	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

$$\text{Example: } 1452^{\circ} = 1450^{\circ} + 2^{\circ} = 32.80 \text{ m. v.} + (2 \times .0229) = 32.84 \text{ m. v.}$$

$$75^{\circ} = 75^{\circ} + 3^{\circ} = 0.95 \text{ m. v.} + (3 \times .0220) = 1.016 \text{ m. v.}$$

Chromel-Alumel Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT

COLD JUNCTION 32° F.

TYPE M. A.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Fahr. per 0.01 M.V.
DEGREES FAHRENHEIT													
0	32	36	41	46	50	55	59	64	68	73	77	0	.45
1	77	82	86	91	95	99	104	108	113	117	121	1	.44
2	121	126	130	135	139	143	148	152	156	161	165	2	.44
3	165	169	173	178	182	186	191	195	199	204	208	3	.43
4	208	212	217	221	225	230	234	238	243	247	251	4	.43
5	251	256	261	265	269	274	278	283	287	291	296	5	.45
6	296	301	305	310	314	319	323	328	332	337	341	6	.45
7	341	346	350	355	359	364	368	373	377	381	386	7	.45
8	386	391	395	400	404	409	413	418	422	426	431	8	.45
9	431	436	440	445	449	453	457	462	466	471	475	9	.44
10	475	480	484	489	493	498	502	506	511	515	519	10	.44
11	519	524	528	532	537	541	546	550	555	559	563	11	.44
12	563	568	572	576	581	585	589	594	598	602	607	12	.44
13	607	611	615	620	624	628	632	636	641	645	650	13	.43
14	650	654	658	663	667	671	675	680	684	688	693	14	.43
15	693	697	701	705	710	714	719	723	727	731	735	15	.42
16	735	740	744	748	752	756	761	765	769	774	778	16	.43
17	778	782	786	791	795	799	804	808	812	816	821	17	.43
18	821	825	829	833	838	842	846	850	855	859	863	18	.42
19	863	867	871	875	880	884	888	893	897	901	905	19	.42
20	905	909	913	918	922	926	930	935	939	943	947	20	.42
21	947	951	956	960	964	968	973	977	981	985	990	21	.43
22	990	994	998	1002	1006	1011	1015	1019	1023	1028	1032	22	.42
23	1032	1036	1040	1044	1049	1053	1057	1061	1065	1070	1074	23	.42
24	1074	1078	1083	1087	1091	1095	1099	1103	1108	1112	1116	24	.42
25	1116	1120	1125	1129	1133	1137	1141	1146	1150	1154	1158	25	.42
26	1158	1163	1167	1171	1175	1180	1184	1188	1193	1197	1201	26	.43
27	1201	1205	1209	1214	1218	1222	1226	1231	1235	1239	1243	27	.42
28	1243	1248	1252	1256	1260	1265	1269	1273	1278	1282	1286	28	.43
29	1286	1290	1295	1299	1303	1307	1312	1316	1320	1325	1329	29	.43
30	1329	1333	1338	1342	1346	1350	1355	1359	1363	1368	1372	30	.43
31	1372	1376	1380	1385	1389	1393	1398	1402	1406	1411	1415	31	.43
32	1415	1420	1424	1428	1433	1437	1441	1446	1450	1454	1459	32	.44
33	1459	1463	1467	1472	1476	1481	1485	1490	1494	1498	1503	33	.44
34	1503	1507	1511	1516	1520	1525	1529	1533	1538	1542	1546	34	.43
35	1546	1551	1556	1560	1564	1569	1573	1578	1582	1586	1591	35	.45
36	1591	1596	1600	1605	1609	1613	1618	1622	1627	1631	1636	36	.45
37	1636	1640	1645	1649	1654	1658	1663	1667	1672	1676	1681	37	.45
38	1681	1685	1690	1694	1699	1703	1708	1712	1717	1721	1726	38	.45
39	1726	1731	1735	1740	1744	1749	1753	1758	1762	1767	1772	39	.46
40	1772	1776	1782	1786	1790	1794	1799	1804	1809	1813	1818	40	.46
41	1818	1822	1827	1831	1836	1841	1846	1850	1855	1860	1864	41	.46
42	1864	1869	1873	1878	1883	1887	1892	1897	1901	1906	1911	42	.47
43	1911	1916	1920	1925	1930	1934	1939	1944	1949	1953	1958	43	.47
44	1958	1963	1967	1972	1977	1981	1986	1991	1996	2001	2005	44	.47
45	2005	2010	2015	2020	2025	2030	2034	2039	2044	2049	2053	45	.48
46	2053	2058	2063	2068	2073	2077	2082	2087	2092	2097	2101	46	.48
47	2101	2106	2111	2116	2121	2126	2131	2136	2141	2146	2151	47	.50
48	2151	2155	2160	2165	2170	2175	2180	2185	2190	2195	2200	48	.49
49	2200	2205	2210	2215	2220	2225	2230	2235	2240	2245	2250	49	.50
50	2250	2255	2260	2265	2270	2275	2280	2285	2290	2295	2300	50	.50
51	2300	2305	2310	2315	2321	2326	2331	2336	2341	2346	2351	51	.51
52	2351	2356	2362	2367	2372	2377	2382	2387	2393	2398	2403	52	.52
53	2403	2408	2413	2418	2424	2429	2434	2439	2444	2450	2455	53	.52
54	2455	2461	2466	2471	2476	2482	2487	2492	2497	2503	2508	54	.53

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right-hand column) for each 0.01 m.v. above the lower printed value.

Example: 35.34 m. v. = 35.30 m. v. + .04 m. v.

$$.04 \text{ m. v.} = \frac{.04}{.01} \times .45^\circ = 1.80^\circ$$

$$35.30 \text{ m. v.} = 1560^\circ \text{F. } 35.34 \text{ m. v.} = 1560^\circ + 1.80^\circ = 1561.80^\circ \text{F.}$$

Plat.-Plat. + 13% Rhodium Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F.

TYPE Q. R.

Deg. F.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	Deg. F.
MILLIVOLTS																	
0	-0.0890	0.220	0.596	1.030	1.504	2.012	2.546	3.102	3.675	4.263	4.867	5.486	6.122	6.773	7.438	8.118	0
5	-0.0756	0.237	0.616	1.052	1.529	2.038	2.573	3.130	3.704	4.293	4.897	5.517	6.154	6.806	7.472	8.152	5
10	-0.0621	0.255	0.637	1.075	1.553	2.064	2.601	3.159	3.733	4.323	4.928	5.548	6.187	6.839	7.505	8.186	10
15	-0.0484	0.273	0.658	1.098	1.578	2.090	2.628	3.187	3.762	4.352	4.959	5.579	6.219	6.872	7.539	8.220	15
20	-0.0346	0.291	0.679	1.121	1.603	2.116	2.656	3.215	3.792	4.382	4.990	5.611	6.251	6.905	7.573	8.255	20
25	-0.0205	0.309	0.700	1.144	1.628	2.142	2.683	3.243	3.821	4.412	5.021	5.643	6.283	6.938	7.607	8.289	25
30	-0.0060	0.327	0.721	1.167	1.653	2.169	2.711	3.272	3.851	4.442	5.052	5.675	6.316	6.972	7.641	8.324	30
35	0.0090	0.345	0.742	1.190	1.678	2.196	2.739	3.300	3.880	4.472	5.083	5.706	6.348	7.005	7.674	8.359	35
40	0.0244	0.364	0.764	1.214	1.703	2.223	2.767	3.329	3.910	4.502	5.114	5.738	6.381	7.038	7.708	8.394	40
45	0.0399	0.382	0.785	1.237	1.728	2.249	2.794	3.357	3.939	4.532	5.144	5.770	6.413	7.071	7.742	8.428	45
50	0.0555	0.400	0.807	1.261	1.753	2.276	2.822	3.386	3.969	4.562	5.175	5.802	6.446	7.104	7.776	8.463	50
55	0.0712	0.419	0.829	1.285	1.778	2.303	2.850	3.415	3.998	4.592	5.206	5.834	6.478	7.137	7.810	8.498	55
60	0.0871	0.439	0.851	1.309	1.804	2.330	2.878	3.444	4.028	4.623	5.237	5.866	6.511	7.170	7.845	8.533	60
65	0.103	0.458	0.873	1.333	1.830	2.356	2.906	3.472	4.057	4.653	5.268	5.898	6.544	7.203	7.879	8.567	65
70	0.119	0.477	0.895	1.357	1.856	2.383	2.934	3.501	4.087	4.684	5.299	5.930	6.577	7.237	7.913	8.602	70
75	0.136	0.496	0.917	1.381	1.881	2.410	2.962	3.530	4.116	4.714	5.330	5.962	6.609	7.270	7.947	8.637	75
80	0.152	0.516	0.939	1.405	1.907	2.438	2.990	3.559	4.145	4.745	5.361	5.994	6.642	7.303	7.981	8.672	80
85	0.169	0.536	0.961	1.429	1.933	2.465	3.018	3.588	4.174	4.775	5.392	6.026	6.674	7.337	8.015	8.706	85
90	0.186	0.556	0.984	1.454	1.959	2.492	3.046	3.617	4.204	4.806	5.423	6.058	6.707	7.371	8.049	8.741	90
95	0.203	0.576	1.007	1.479	1.985	2.519	3.074	3.646	4.233	4.836	5.454	6.090	6.740	7.404	8.083	8.776	95
100	0.220	0.596	1.030	1.504	2.012	2.546	3.102	3.675	4.263	4.867	5.486	6.122	6.773	7.438	8.118	8.811	100
M. V. per °F.	0.00323	0.00376	0.00434	0.00474	0.00508	0.00534	0.00556	0.00573	0.00588	0.00604	0.00619	0.00636	0.00651	0.00665	0.00680	0.00693	M. V. per °F.

Deg. F.	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	Deg. F.
MILLIVOLTS																
0	8.811	9.518	10.237	10.970	11.720	12.478	13.242	14.010	14.777	15.543	16.309	17.073	17.833	18.588	19.342	0
5	8.845	9.553	10.273	11.007	11.758	12.516	13.280	14.048	14.815	15.581	16.347	17.111	17.871	18.626	19.380	5
10	8.880	9.589	10.310	11.045	11.796	12.554	13.318	14.086	14.853	15.619	16.385	17.149	17.909	18.664	19.417	10
15	8.915	9.624	10.346	11.082	11.833	12.592	13.356	14.124	14.892	15.657	16.424	17.187	17.947	18.702	19.455	15
20	8.951	9.660	10.383	11.119	11.871	12.631	13.395	14.163	14.930	15.695	16.462	17.225	17.985	18.739	19.492	20
25	8.986	9.695	10.419	11.156	11.909	12.669	13.433	14.201	14.968	15.734	16.501	17.264	18.023	18.777	19.530	25
30	9.021	9.731	10.456	11.194	11.947	12.707	13.472	14.240	15.006	15.772	16.539	17.302	18.060	18.815	19.567	30
35	9.056	9.767	10.492	11.231	11.985	12.745	13.510	14.278	15.045	15.811	16.577	17.340	18.098	18.853	19.605	35
40	9.092	9.803	10.529	11.269	12.023	12.783	13.549	14.316	15.083	15.849	16.615	17.377	18.135	18.891	19.642	40
45	9.127	9.839	10.565	11.306	12.061	12.821	13.587	14.355	15.122	15.887	16.654	17.415	18.173	18.929	19.680	45
50	9.162	9.875	10.602	11.344	12.099	12.860	13.625	14.393	15.160	15.925	16.692	17.453	18.211	18.966	19.717	50
55	9.197	9.911	10.638	11.382	12.136	12.898	13.663	14.432	15.199	15.964	16.731	17.492	18.249	19.004	19.755	55
60	9.233	9.947	10.675	11.420	12.174	12.936	13.702	14.470	15.237	16.002	16.769	17.530	18.286	19.041	19.793	60
65	9.268	9.983	10.712	11.457	12.212	12.974	13.740	14.509	15.275	16.041	16.807	17.568	18.324	19.079	19.830	65
70	9.304	10.019	10.749	11.495	12.250	13.012	13.779	14.547	15.313	16.079	16.845	17.605	18.362	19.117	19.867	70
75	9.339	10.055	10.785	11.532	12.288	13.050	13.817	14.586	15.351	16.117	16.883	17.643	18.400	19.155	19.905	75
80	9.375	10.091	10.822	11.570	12.326	13.089	13.856	14.624	15.389	16.155	16.921	17.682	18.437	19.192	19.942	80
85	9.410	10.127	10.859	11.607	12.364	13.127	13.894	14.663	15.428	16.194	16.959	17.720	18.475	19.230	19.980	85
90	9.446	10.164	10.896	11.645	12.402	13.166	13.933	14.701	15.466	16.232	16.997	17.758	18.513	19.267	20.017	90
95	9.482	10.200	10.933	11.682	12.440	13.204	13.971	14.739	15.505	16.271	17.035	17.796	18.551	19.305	20.055	95
100	9.518	10.237	10.970	11.720	12.478	13.242	14.010	14.777	15.543	16.309	17.073	17.833	18.588	19.342	20.093	100
M. V. per °F.	0.00707	0.00719	0.00733	0.00750	0.00758	0.00764	0.00768	0.00767	0.00766	0.00766	0.00764	0.00760	0.00755	0.00754	0.00751	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

$$\text{Example: } 2452^{\circ} = 2450^{\circ} + 2^{\circ} = 15.160 \text{ m. v.} + (2 \times .00766) = 15.175 \text{ m. v.}$$

$$82^{\circ} = 80^{\circ} + 2^{\circ} = .162 \text{ m. v.} + (2 \times .00323) = .168 \text{ m. v.}$$

Plat.- Plat. + 13% Rhodium Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT

COLD JUNCTION 32° F

TYPE Q. R.

Millivolts	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	Millivolts	Dep. Fahr. per 0.005 M. V.
DEGREES FAHRENHEIT																							
0	32	48	64	79	94	109	123	136	150	163	176	189	201	213	225	237	249	260	271	282	294	0	1.31
1	294	305	316	326	337	348	358	369	379	389	399	409	420	430	440	449	459	469	479	488	498	1	1.02
2	498	507	517	526	536	545	555	564	573	582	592	601	610	619	628	637	646	655	664	673	682	2	.93
3	682	691	700	709	717	726	735	744	752	761	770	779	787	796	804	813	821	830	838	847	855	3	.86
4	855	864	872	881	889	898	906	915	923	931	940	948	956	965	973	981	989	997	1005	1014	1022	4	.84
5	1022	1030	1038	1046	1054	1062	1070	1078	1086	1094	1102	1110	1118	1126	1134	1142	1150	1158	1165	1173	1181	5	.80
6	1181	1189	1197	1204	1212	1220	1228	1235	1243	1251	1258	1266	1274	1281	1289	1297	1304	1312	1319	1327	1334	6	.77
7	1334	1342	1349	1357	1365	1372	1380	1387	1394	1402	1409	1417	1424	1431	1439	1446	1454	1461	1468	1476	1483	7	.75
8	1483	1490	1497	1505	1512	1519	1527	1534	1541	1548	1555	1563	1570	1577	1584	1591	1599	1606	1613	1620	1627	8	.72
9	1627	1634	1641	1648	1655	1662	1669	1677	1684	1691	1698	1705	1712	1719	1726	1733	1740	1747	1754	1761	1767	9	.70
10	1767	1774	1781	1788	1795	1802	1809	1816	1822	1829	1836	1843	1850	1857	1863	1870	1877	1884	1891	1897	1904	10	.69
11	1904	1911	1917	1924	1931	1938	1944	1951	1957	1964	1971	1977	1984	1991	1997	2004	2011	2017	2024	2030	2037	11	.67
12	2037	2044	2050	2057	2063	2070	2077	2083	2090	2096	2103	2110	2116	2123	2129	2136	2142	2149	2155	2162	2168	12	.66
13	2168	2175	2181	2188	2195	2201	2208	2214	2221	2227	2234	2240	2247	2253	2260	2266	2273	2279	2286	2293	2299	13	.66
14	2299	2305	2312	2318	2325	2331	2338	2344	2351	2357	2364	2370	2377	2383	2390	2397	2403	2410	2416	2423	2429	14	.65
15	2429	2436	2442	2449	2455	2462	2468	2475	2481	2488	2494	2501	2508	2514	2521	2527	2534	2540	2547	2553	2560	15	.65
16	2560	2566	2573	2579	2586	2592	2599	2605	2612	2618	2625	2632	2638	2645	2651	2658	2664	2671	2677	2684	2690	16	.65
17	2690	2697	2704	2710	2717	2723	2730	2736	2743	2750	2756	2763	2769	2776	2782	2789	2796	2802	2809	2815	2822	17	.66
18	2822	2829	2835	2842	2849	2855	2862	2868	2875	2882	2888	2895	2902	2908	2915	2921	2928	2935	2941	2948	2955	18	.66
19	2955	2961	2968	2974	2981	2988	2994	3001	3008	3014	3021	3028	3034	3041	3048	3054	3061	3068	3074	3081	3088	19	.67

To interpolate between two printed values, add the increase in degrees per 0.005 m.v. (shown in the right-hand column) for each 0.005 m.v. above the lower printed value.

Example: 15.37 m. v. = 15.35 m. v. + .02 m. v.
 $.02 \text{ m. v.} \times \frac{.02}{.005} \times .85^\circ = 2.60^\circ$
 15.35 m. v. = 2475°F. 15.37 m. v. = 2475° + 2.60° = 2477.6°F.

Plat.-Plat. + 10% Rhodium Thermocouple

TO CONVERT DEGREES FAHRENHEIT TO MILLIVOLTS

COLD JUNCTION 32° F.

TYPE HER.

Deg. F.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	Deg. F.
MILLIVOLTS																	
0	-0.0920	0.221	0.595	1.016	1.473	1.956	2.457	2.975	3.505	4.044	4.594	5.155	5.725	6.307	6.898	7.500	0
5	-0.0778	0.239	0.615	1.038	1.497	1.980	2.482	3.001	3.532	4.071	4.621	5.183	5.754	6.336	6.928	7.530	5
10	-0.0636	0.257	0.635	1.060	1.521	2.005	2.508	3.028	3.559	4.098	4.649	5.211	5.783	6.366	6.958	7.561	10
15	-0.0494	0.274	0.655	1.082	1.544	2.030	2.534	3.054	3.585	4.125	4.677	5.239	5.812	6.395	6.987	7.591	15
20	-0.0351	0.292	0.676	1.105	1.568	2.055	2.560	3.081	3.612	4.153	4.705	5.268	5.841	6.424	7.017	7.621	20
25	-0.0207	0.310	0.696	1.127	1.592	2.080	2.585	3.107	3.639	4.180	4.733	5.296	5.869	6.453	7.047	7.651	25
30	-0.0060	0.328	0.717	1.150	1.616	2.105	2.611	3.133	3.667	4.208	4.761	5.324	5.898	6.483	7.077	7.682	30
35	0.0090	0.346	0.737	1.173	1.640	2.130	2.637	3.159	3.694	4.235	4.789	5.352	5.927	6.512	7.107	7.713	35
40	0.0243	0.365	0.758	1.196	1.664	2.155	2.663	3.186	3.720	4.263	4.817	5.381	5.956	6.542	7.137	7.744	40
45	0.0398	0.383	0.779	1.218	1.688	2.180	2.689	3.212	3.747	4.290	4.845	5.408	5.985	6.571	7.167	7.774	45
50	0.0555	0.401	0.800	1.241	1.712	2.205	2.715	3.239	3.774	4.318	4.873	5.438	6.015	6.601	7.198	7.805	50
55	0.0714	0.420	0.821	1.264	1.736	2.230	2.741	3.266	3.801	4.345	4.901	5.466	6.044	6.630	7.228	7.835	55
60	0.0875	0.439	0.843	1.287	1.760	2.255	2.767	3.293	3.828	4.373	4.929	5.495	6.073	6.660	7.258	7.866	60
65	0.104	0.458	0.864	1.310	1.784	2.280	2.793	3.319	3.855	4.400	4.957	5.524	6.102	6.690	7.288	7.897	65
70	0.120	0.477	0.886	1.333	1.808	2.305	2.819	3.346	3.882	4.428	4.985	5.553	6.132	6.720	7.318	7.928	70
75	0.137	0.496	0.907	1.356	1.832	2.330	2.845	3.372	3.909	4.455	5.013	5.581	6.161	6.749	7.348	7.958	75
80	0.153	0.516	0.929	1.380	1.857	2.356	2.871	3.399	3.936	4.483	5.042	5.610	6.190	6.779	7.379	7.989	80
85	0.170	0.535	0.950	1.403	1.881	2.381	2.897	3.425	3.963	4.511	5.070	5.638	6.219	6.808	7.409	8.020	85
90	0.187	0.555	0.972	1.426	1.906	2.406	2.923	3.452	3.990	4.539	5.098	5.667	6.249	6.838	7.439	8.051	90
95	0.204	0.575	0.994	1.449	1.931	2.431	2.949	3.478	4.017	4.566	5.126	5.696	6.278	6.868	7.469	8.081	95
100	0.221	0.595	1.016	1.473	1.956	2.457	2.975	3.505	4.044	4.594	5.155	5.725	6.307	6.898	7.500	8.112	100
M. V. per °F.	0.00325	0.00374	0.00421	0.00457	0.00483	0.00501	0.00518	0.00530	0.00539	0.00550	0.00561	0.00570	0.00582	0.00591	0.00602	0.00612	M. V. per °F.

Deg. F.	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	Deg. F.
MILLIVOLTS																	
0	8.112	8.734	9.365	10.007	10.657	11.316	11.977	12.642	13.305	13.968	14.629	15.288	15.943	16.596	17.247	17.892	0
5	8.143	8.765	9.397	10.039	10.690	11.349	12.010	12.675	13.339	14.001	14.662	15.321	15.976	16.629	17.279	17.920	5
10	8.174	8.796	9.429	10.071	10.723	11.382	12.043	12.708	13.372	14.034	14.695	15.353	16.009	16.661	17.311	17.957	10
15	8.205	8.827	9.461	10.103	10.756	11.415	12.076	12.741	13.405	14.067	14.728	15.386	16.042	16.694	17.344	17.989	15
20	8.236	8.859	9.493	10.136	10.789	11.448	12.110	12.775	13.438	14.100	14.761	15.418	16.074	16.726	17.376	18.021	20
25	8.267	8.890	9.525	10.168	10.822	11.481	12.143	12.808	13.472	14.133	14.794	15.451	16.107	16.759	17.408	...	25
30	8.298	8.922	9.557	10.201	10.855	11.514	12.177	12.841	13.505	14.166	14.826	15.484	16.139	16.791	17.440	...	30
35	8.329	8.953	9.589	10.233	10.887	11.547	12.210	12.874	13.538	14.200	14.859	15.517	16.172	16.824	17.473	...	35
40	8.360	8.985	9.621	10.265	10.920	11.580	12.243	12.907	13.571	14.233	14.892	15.550	16.205	16.856	17.505	...	40
45	8.391	9.016	9.653	10.298	10.953	11.613	12.276	12.941	13.604	14.266	14.925	15.583	16.238	16.889	17.538	...	45
50	8.422	9.048	9.685	10.331	10.986	11.646	12.310	12.974	13.637	14.299	14.958	15.615	16.270	16.922	17.570	...	50
55	8.453	9.079	9.717	10.363	11.019	11.679	12.343	13.007	13.670	14.332	14.991	15.648	16.303	16.955	17.602	...	55
60	8.484	9.111	9.749	10.396	11.052	11.712	12.376	13.040	13.703	14.365	15.024	15.680	16.335	16.987	17.634	...	60
65	8.515	9.143	9.781	10.428	11.085	11.745	12.409	13.074	13.737	14.398	15.057	15.713	16.368	17.020	17.667	...	65
70	8.546	9.175	9.813	10.461	11.118	11.778	12.442	13.107	13.770	14.431	15.090	15.746	16.401	17.052	17.699	...	70
75	8.577	9.206	9.845	10.493	11.151	11.811	12.475	13.140	13.803	14.464	15.123	15.779	16.434	17.085	17.731	...	75
80	8.609	9.238	9.877	10.526	11.184	11.844	12.509	13.173	13.836	14.497	15.156	15.812	16.466	17.117	17.763	...	80
85	8.640	9.270	9.909	10.558	11.217	11.877	12.542	13.206	13.869	14.530	15.189	15.845	16.499	17.150	17.796	...	85
90	8.671	9.302	9.942	10.591	11.250	11.911	12.575	13.239	13.902	14.563	15.222	15.878	16.531	17.182	17.828	...	90
95	8.702	9.333	9.974	10.624	11.283	11.944	12.608	13.272	13.935	14.596	15.255	15.911	16.564	17.215	17.860	...	95
100	8.734	9.365	10.007	10.657	11.316	11.977	12.642	13.305	13.968	14.629	15.288	15.943	16.596	17.247	17.892	...	100
M. V. per °F.	0.00622	0.00631	0.00642	0.00650	0.00659	0.00661	0.00665	0.00663	0.00663	0.00661	0.00659	0.00655	0.00653	0.00651	0.00645	...	M. V. per °F.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

$$\begin{aligned} \text{Example: } 2452^{\circ} &= 2450^{\circ} + 2^{\circ} = 13.637 \text{ m. v.} + (2 \times .00663) = 13.650 \text{ m. v.} \\ 67^{\circ} &= 66^{\circ} + 1^{\circ} = .104 \text{ m. v.} + (1 \times .00325) = .110 \text{ m. v.} \end{aligned}$$

Plat.- Plat. + 10% Rhodium Thermocouple

COLD JUNCTION 32°F.

TO CONVERT MILLIVOLTS TO DEGREES FAHRENHEIT

TYPE HER.

Millivolts	DEGREES FAHRENHEIT																Millivolts			Deg. Fahr. per 0.005 M. V.			
	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90		0.95	1.00	
0	32	48	64	79	94	108	122	136	150	163	176	189	201	214	226	238	250	262	273	285	296	0	1.32
1	296	308	319	330	341	352	363	374	384	395	406	416	427	437	448	458	468	479	489	499	509	1	1.07
2	509	519	529	539	549	559	569	579	589	599	608	618	628	638	647	657	666	676	686	695	705	2	.98
3	705	714	724	733	743	752	761	771	780	790	799	808	818	827	836	846	855	864	873	883	892	3	.94
4	892	901	910	920	929	938	947	956	965	974	983	992	1001	1010	1019	1028	1037	1046	1055	1064	1073	4	.91
5	1073	1082	1090	1099	1108	1117	1126	1135	1143	1152	1161	1170	1178	1187	1196	1204	1213	1222	1230	1239	1248	5	.88
6	1248	1256	1265	1273	1282	1290	1299	1307	1316	1324	1333	1341	1350	1358	1367	1375	1384	1392	1400	1409	1417	6	.85
7	1417	1426	1434	1442	1450	1459	1467	1475	1484	1492	1500	1508	1517	1525	1533	1541	1549	1557	1566	1574	1582	7	.83
8	1582	1590	1598	1606	1614	1622	1630	1639	1647	1655	1663	1671	1679	1687	1695	1703	1711	1719	1727	1735	1742	8	.80
9	1742	1750	1758	1766	1774	1782	1790	1798	1806	1813	1821	1829	1837	1845	1852	1860	1868	1876	1884	1891	1899	9	.79
10	1899	1907	1915	1922	1930	1938	1945	1953	1961	1968	1976	1984	1991	1999	2007	2014	2022	2029	2037	2045	2052	10	.77
11	2052	2060	2067	2075	2083	2090	2098	2105	2113	2120	2128	2136	2143	2151	2158	2166	2173	2181	2188	2196	2204	11	.76
12	2204	2211	2219	2226	2234	2241	2249	2256	2264	2271	2279	2286	2294	2301	2309	2316	2324	2331	2339	2347	2354	12	.75
13	2354	2362	2369	2377	2384	2392	2399	2407	2414	2422	2429	2437	2444	2452	2460	2467	2475	2482	2490	2497	2505	13	.75
14	2505	2512	2520	2528	2535	2543	2550	2558	2565	2573	2580	2588	2596	2603	2611	2618	2626	2634	2641	2649	2656	14	.76
15	2656	2664	2672	2679	2687	2693	2702	2710	2717	2725	2732	2740	2748	2755	2763	2771	2778	2786	2793	2801	2809	15	.77
16	2809	2816	2824	2832	2839	2847	2855	2862	2870	2878	2885	2893	2901	2908	2916	2924	2931	2939	2947	2954	2962	16	.77
17	2962	2970	2977	2985	2993	3001	3008	3016	3024	3032	3039	3047	3055	3062	3070	3078	3086	3093	3101	3109	3117	17	.78

To interpolate between two printed values, add the increase in degrees per 0.005 m.v. (shown in the right-hand column) for each 0.005 m.v. above the lower printed value.

Example: 14.73 m. v. = 14.70 m. v. + .03 m. v.
.03 m. v. = .005 X .76° = 4.56°
14.70 m. v. = 2511°F. 14.73 m. v. = 2511° + 4.56° = 2515.56°F.

Copper-Constantan Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS
TYPE C. C.

COLD JUNCTION 0° C.

Deg. Cent.	-100	-0	+0	+100	+200	+300	Deg. Cent.
MILLIVOLTS							
0	-3.35	-0.000	0.000	4.28	9.29	14.86	0
2	-3.40	-0.077	0.077	4.37	9.39	14.98	2
4	-3.46	-0.153	0.155	4.46	9.50	15.09	4
6	-3.52	-0.230	0.233	4.56	9.60	15.21	6
8	-3.57	-0.306	0.311	4.65	9.71	15.33	8
10	-3.62	-0.381	0.390	4.75	9.82	15.44	10
12	-3.68	-0.456	0.469	4.84	9.93	15.56	12
14	-3.73	-0.531	0.548	4.94	10.03	15.68	14
16	-3.78	-0.605	0.627	5.03	10.14	15.79	16
18	-3.83	-0.679	0.707	5.13	10.25	15.91	18
20	-3.89	-0.752	0.787	5.23	10.36	16.03	20
22	-3.94	-0.825	0.868	5.32	10.47	16.15	22
24	-3.99	-0.898	0.949	5.42	10.58	16.27	24
26	-4.04	-0.970	1.03	5.52	10.69	16.38	26
28	-4.09	-1.04	1.11	5.61	10.79	16.50	28
30	-4.14	-1.11	1.19	5.71	10.90	16.62	30
32	-4.19	-1.19	1.28	5.81	11.01	16.74	32
34	-4.23	-1.26	1.36	5.91	11.12	16.86	34
36	-4.28	-1.33	1.44	6.00	11.23	16.98	36
38	-4.33	-1.40	1.53	6.10	11.34	17.10	38
40	-4.38	-1.47	1.61	6.20	11.45	17.22	40
42	-4.42	-1.53	1.69	6.30	11.57	17.34	42
44	-4.47	-1.60	1.78	6.40	11.68	17.46	44
46	-4.51	-1.67	1.86	6.50	11.79	17.58	46
48	-4.56	-1.74	1.95	6.60	11.90	17.70	48
50	-4.60	-1.81	2.03	6.70	12.01	17.82	50
52	-4.65	-1.87	2.12	6.80	12.12	17.94	52
54	-4.69	-1.94	2.21	6.90	12.23	18.06	54
56	-4.73	-2.01	2.29	7.00	12.35	18.18	56
58	-4.77	-2.07	2.38	7.10	12.46	18.30	58
60	-4.82	-2.14	2.47	7.21	12.57	18.42	60
62	-4.86	-2.20	2.55	7.31	12.68	18.54	62
64	-4.90	-2.27	2.64	7.41	12.80	18.66	64
66	-4.94	-2.33	2.73	7.51	12.91	18.78	66
68	-4.98	-2.39	2.82	7.61	13.02	18.90	68
70	-5.02	-2.46	2.91	7.72	13.14	19.02	70
72	-5.06	-2.52	3.00	7.82	13.25	19.15	72
74	-5.09	-2.58	3.09	7.92	13.36	19.27	74
76	-5.13	-2.64	3.18	8.03	13.48	19.39	76
78	-5.17	-2.70	3.27	8.13	13.59	19.51	78
80	-5.20	-2.76	3.36	8.23	13.71	19.64	80
82	-5.24	-2.83	3.45	8.34	13.82	19.76	82
84	-5.28	-2.89	3.54	8.44	13.93	19.88	84
86	-5.31	-2.95	3.63	8.55	14.05	.....	86
88	-5.34	-3.00	3.72	8.65	14.16	.....	88
90	-5.38	-3.06	3.81	8.76	14.28	.....	90
92	-5.41	-3.12	3.90	8.86	14.40	.....	92
94	-5.44	-3.18	4.00	8.97	14.51	.....	94
96	-5.48	-3.24	4.09	9.07	14.63	.....	96
98	-5.51	-3.29	4.18	9.18	14.74	.....	98
100	-5.54	-3.35	4.28	9.29	14.86	.....	100
M. V. per °C.	0.021	0.033	0.043	0.052	0.057	0.060	M. V. per °C.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $-149^{\circ} = -(148^{\circ} + 1^{\circ}) = -(4.56 + 0.021) \text{ m. v.} = -4.58 \text{ m. v.}$
(Negative Degrees)
Example: $325^{\circ} = 324^{\circ} + 1^{\circ} = (18.27 + 0.060) \text{ m. v.} = 18.33 \text{ m. v.}$
(Positive Degrees)

Copper-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE
TYPE C. C.

COLD JUNCTION 0° C.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Cent. per 0.01 M.V.
DEGREES CENTIGRADE													
-5	-169	-174	-180	-186	-192	-198	-204	....	....	....	....	-5	.58
-4	-124	-128	-132	-137	-141	-146	-150	-154	-159	-164	-169	-4	.45
-3	-88	-91	-94	-98	-102	-105	-109	-113	-116	-120	-124	-3	.36
-2	-56	-59	-62	-65	-68	-71	-74	-78	-81	-84	-88	-2	.32
-1	-27	-30	-32	-35	-38	-41	-44	-47	-50	-53	-56	-1	.29
-0	0	-3	-5	-8	-11	-13	-16	-19	-22	-24	-27	-0	.27
+0	0	3	5	8	10	13	15	18	20	23	25	+0	.26
1	25	28	30	32	35	37	40	42	44	47	49	1	.24
2	49	52	54	56	58	61	63	65	68	70	72	2	.23
3	72	74	76	79	81	83	85	88	90	92	94	3	.22
4	94	96	98	101	103	105	107	109	111	113	115	4	.21
5	115	117	120	122	124	126	128	130	132	134	136	5	.21
6	136	138	140	142	144	146	148	150	152	154	156	6	.20
7	156	158	160	162	164	166	168	170	172	174	176	7	.20
8	176	177	179	181	183	185	187	189	191	193	195	8	.19
9	195	196	198	200	202	204	206	208	210	212	213	9	.19
10	213	215	217	219	221	223	224	226	228	230	232	10	.18
11	232	234	235	237	239	241	243	244	246	248	250	11	.18
12	250	252	253	255	257	259	260	262	264	266	268	12	.18
13	268	269	271	273	275	276	278	280	282	283	285	13	.17
14	285	287	289	290	292	294	296	297	299	301	302	14	.17
15	302	304	306	308	309	311	313	314	316	318	320	15	.18
16	320	321	323	325	326	328	330	331	333	335	336	16	.17
17	336	338	340	341	343	345	346	348	350	351	353	17	.17
18	353	355	356	358	360	361	363	365	367	368	370	18	.17
19	370	371	373	374	376	378	380	381	383	384	386	19	.16

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right hand column) for each 0.01 m.v. above the lower printed value.

Example: - 3.54 m. v. = - (3.50 + 0.04) m. v.
(Negative m. v.) $0.04 \text{ m. v.} = \frac{0.04}{0.01} \times 0.36^\circ = 1.44^\circ \text{ C.}$
- 3.50 m. v. = - 105° C.
- 3.54 m. v. = - (105° + 1.44°) = - 106.44° C.

Example: 12.25 m. v. = 12.20 m. v. + 0.05 m. v.
(Positive m. v.) $0.05 \text{ m. v.} = \frac{0.05}{0.01} \times 0.18^\circ = 0.90^\circ \text{ C.}$
12.20 m. v. = 253° C.
12.25 m. v. = 253° + 0.90° = 253.9° C.

Special (B. S.) Iron-Constantan Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

COLD JUNCTION 0° C.

TYPE B. S.

Do not confuse with I. C. Thermocouple

Deg. Cent.	-100	-0	+0	100	200	300	400	500	600	700	800	900	Deg. Cent.
MILLIVOLTS													
0	-4.82	-0.00	0.00	5.40	11.00	16.56	22.07	27.58	33.27	39.30	45.72	52.29	0
2	-4.91	-0.104	0.11	5.51	11.11	16.68	22.18	27.69	33.39	39.43	45.85	52.41	2
4	-4.99	-0.209	0.21	5.62	11.22	16.79	22.29	27.80	33.50	39.55	45.98	52.52	4
6	-5.08	-0.313	0.31	5.73	11.33	16.90	22.40	27.91	33.62	39.68	46.11	52.64	6
8	-5.16	-0.418	0.42	5.84	11.44	17.01	22.51	28.03	33.74	39.80	46.24	52.76	8
10	-5.25	-0.522	0.52	5.95	11.56	17.12	22.62	28.14	33.86	39.93	46.38	52.88	10
12	-5.33	-0.625	0.63	6.06	11.67	17.23	22.73	28.25	33.97	40.05	46.51	53.00	12
14	-5.41	-0.727	0.73	6.17	11.78	17.34	22.84	28.36	34.09	40.18	46.64	53.12	14
16	-5.49	-0.830	0.84	6.29	11.89	17.45	22.95	28.47	34.21	40.31	46.77	53.23	16
18	-5.57	-0.932	0.94	6.40	12.00	17.56	23.06	28.59	34.33	40.43	46.90	53.35	18
20	-5.66	-1.04	1.05	6.51	12.11	17.67	23.17	28.70	34.45	40.56	47.03	53.47	20
22	-5.74	-1.14	1.16	6.62	12.23	17.78	23.28	28.81	34.57	40.69	47.16	53.59	22
24	-5.81	-1.24	1.26	6.73	12.34	17.89	23.39	28.93	34.68	40.81	47.30	53.71	24
26	-5.89	-1.34	1.37	6.84	12.45	18.00	23.50	29.04	34.80	40.94	47.43	53.82	26
28	-5.97	-1.44	1.48	6.95	12.56	18.11	23.61	29.15	34.92	41.07	47.56	53.94	28
30	-6.05	-1.54	1.58	7.07	12.67	18.22	23.72	29.26	35.04	41.20	47.69	54.06	30
32	-6.13	-1.64	1.69	7.18	12.78	18.33	23.83	29.38	35.16	41.33	47.82	54.18	32
34	-6.21	-1.74	1.80	7.29	12.90	18.44	23.94	29.49	35.28	41.45	47.95	54.30	34
36	-6.28	-1.84	1.91	7.40	13.01	18.55	24.05	29.60	35.40	41.58	48.08	54.42	36
38	-6.36	-1.94	2.01	7.51	13.12	18.66	24.16	29.72	35.52	41.71	48.22	54.53	38
40	-6.43	-2.04	2.12	7.63	13.23	18.77	24.27	29.83	35.64	41.84	48.35	54.65	40
42	-6.51	-2.13	2.23	7.74	13.34	18.88	24.38	29.94	35.76	41.97	48.48	54.77	42
44	-6.58	-2.23	2.34	7.85	13.45	18.99	24.49	30.05	35.88	42.09	48.61	54.89	44
46	-6.65	-2.33	2.44	7.96	13.57	19.10	24.60	30.17	36.00	42.22	48.74	55.01	46
48	-6.73	-2.42	2.55	8.07	13.68	19.21	24.71	30.28	36.12	42.35	48.87	55.13	48
50	-6.80	-2.52	2.66	8.19	13.79	19.32	24.82	30.39	36.24	42.48	49.01	55.25	50
52	-6.87	-2.62	2.77	8.30	13.90	19.43	24.93	30.51	36.36	42.61	49.14	55.37	52
54	-6.94	-2.72	2.88	8.41	14.01	19.54	25.04	30.62	36.48	42.74	49.27	55.48	54
56	-7.01	-2.81	2.98	8.52	14.12	19.65	25.15	30.73	36.60	42.87	49.40	55.60	56
58	-7.08	-2.91	3.09	8.63	14.24	19.76	25.26	30.85	36.72	43.00	49.53	55.72	58
60	-7.15	-3.00	3.20	8.75	14.35	19.87	25.37	30.96	36.84	43.12	49.66	55.84	60
62	-7.22	-3.10	3.31	8.86	14.46	19.98	25.47	31.08	36.96	43.25	49.79	55.96	62
64	-7.28	-3.19	3.42	8.97	14.57	20.09	25.58	31.19	37.08	43.38	49.92	56.08	64
66	-7.35	-3.29	3.53	9.09	14.68	20.20	25.69	31.30	37.21	43.51	50.05	56.20	66
68	-7.41	-3.38	3.64	9.20	14.79	20.31	25.80	31.42	37.33	43.64	50.19	56.32	68
70	-7.48	-3.47	3.75	9.31	14.90	20.42	25.91	31.53	37.45	43.77	50.32	56.43	70
72	-7.54	-3.57	3.86	9.42	15.01	20.53	26.02	31.65	37.57	43.90	50.45	56.55	72
74	-7.60	-3.66	3.96	9.54	15.12	20.64	26.13	31.76	37.69	44.03	50.58	56.67	74
76	-7.66	-3.75	4.07	9.65	15.23	20.75	26.24	31.88	37.81	44.16	50.71	56.79	76
78	-7.73	-3.84	4.18	9.76	15.35	20.86	26.35	31.99	37.94	44.29	50.84	56.91	78
80	-7.79	-3.93	4.29	9.87	15.46	20.97	26.47	32.11	38.06	44.42	50.97	57.03	80
82	-7.85	-4.02	4.40	9.99	15.57	21.08	26.58	32.22	38.18	44.55	51.10	57.15	82
84	-7.90	-4.11	4.51	10.10	15.68	21.19	26.69	32.34	38.31	44.68	51.24	57.27	84
86	-7.96	-4.20	4.62	10.21	15.79	21.30	26.80	32.45	38.43	44.81	51.37	57.39	86
88	-8.02	-4.29	4.73	10.32	15.90	21.41	26.91	32.57	38.55	44.94	51.50	57.50	88
90	-8.07	-4.38	4.85	10.44	16.01	21.52	27.02	32.69	38.68	45.07	51.63	57.62	90
92	-8.12	-4.47	4.96	10.55	16.12	21.63	27.13	32.80	38.80	45.20	51.76	57.74	92
94	-8.17	-4.56	5.07	10.66	16.23	21.74	27.24	32.92	38.93	45.33	51.89	57.86	94
96	-8.23	-4.65	5.18	10.77	16.34	21.85	27.35	33.03	39.05	45.46	52.02	57.98	96
98	-8.28	-4.74	5.29	10.88	16.45	21.96	27.46	33.15	39.17	45.59	52.15	58.10	98
100	-8.33	-4.82	5.40	11.00	16.56	22.07	27.58	33.27	39.30	45.72	52.29	58.22	100
M. V. per °C.	0.035	0.048	0.054	0.056	0.056	0.055	0.055	0.057	0.060	0.064	0.066	0.057	M. V. per °C.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the printed value.

Example: $-165^{\circ} = -(164^{\circ} + 1^{\circ}) = -(7.28 + 0.035) \text{ m. v.} = -7.315 \text{ m. v.}$
(Negative Degrees)

Example: $81.5^{\circ} = 80^{\circ} + 1.5^{\circ} = (4.29 + 1.5 \times 0.054) \text{ m. v.} = 4.371 \text{ m. v.}$
(Positive Degrees)

Special (B. S.) Iron-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE

COLD JUNCTION 0° C.

TYPE B. S.

Do not confuse with I. C. Thermocouple

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Cent. per 0.01 M.V.
DEGREES CENTIGRADE													
-8	-188	-191	-195	-199	-203	-207	-211	-215	-218	-221	-224	-8	.38
-7	-156	-158	-161	-164	-167	-171	-174	-177	-180	-184	-188	-7	.32
-6	-129	-131	-134	-137	-139	-142	-144	-147	-150	-153	-156	-6	.27
-5	-104	-107	-109	-111	-114	-116	-119	-121	-124	-126	-129	-5	.25
-4	-82	-84	-86	-88	-90	-93	-95	-97	-99	-102	-104	-4	.22
-3	-60	-62	-64	-67	-69	-71	-73	-75	-77	-79	-82	-3	.22
-2	-39	-41	-43	-45	-48	-50	-52	-54	-56	-58	-60	-2	.21
-1	-19	-21	-23	-25	-27	-29	-31	-33	-35	-37	-39	-1	.20
-0	-0	-2	-4	-6	-7	-9	-11	-13	-15	-17	-19	-0	.19
+0	0.00	2	4	6	8	10	12	13	15	17	19	+0	.19
1	19	21	23	25	27	28	30	32	34	36	38	1	.19
2	38	40	42	43	45	47	49	51	53	54	56	2	.18
3	56	58	60	62	64	66	67	69	71	73	75	3	.18
4	75	77	78	80	82	84	86	88	89	91	93	4	.18
5	93	95	96	98	100	102	104	105	107	109	111	5	.18
6	111	113	114	116	118	120	122	124	125	127	130	6	.18
7	129	131	132	134	136	138	140	141	143	145	147	7	.18
8	147	148	150	152	154	156	157	159	161	163	164	8	.18
9	164	166	168	170	172	173	175	177	179	180	182	9	.18
10	182	184	186	188	189	191	193	195	197	198	200	10	.18
11	200	202	204	206	207	209	211	213	214	216	218	11	.18
12	218	220	222	223	225	227	229	230	232	234	236	12	.18
13	236	238	240	241	243	245	247	248	250	252	254	13	.18
14	254	256	257	259	261	263	265	266	268	270	272	14	.18
15	272	274	275	277	279	281	282	284	286	288	290	15	.18
16	290	292	293	295	297	299	301	302	304	306	308	16	.18
17	308	310	311	313	315	317	319	320	322	324	326	17	.18
18	326	328	330	331	333	335	337	339	340	342	344	18	.18
19	344	346	348	350	351	353	355	357	359	360	362	19	.18
20	362	364	366	368	369	371	373	375	377	379	381	20	.18
21	381	382	384	386	388	390	392	393	395	397	399	21	.18
22	399	401	402	404	406	408	410	411	413	415	417	22	.18
23	417	419	420	422	424	426	428	430	432	433	435	23	.18
24	435	437	439	441	442	444	446	448	450	452	453	24	.18
25	453	455	457	459	461	462	464	466	468	470	472	25	.18
26	472	473	475	477	479	481	482	484	486	488	490	26	.18
27	490	491	493	495	497	499	500	502	504	506	508	27	.18
28	508	509	511	513	515	516	518	520	522	524	525	28	.18
29	525	527	529	531	532	534	536	538	540	541	543	29	.18
30	543	545	547	548	550	552	554	556	557	559	561	30	.18
31	561	562	564	566	568	569	571	573	575	576	578	31	.18
32	578	580	582	583	585	587	589	590	592	594	596	32	.18
33	596	597	599	601	603	604	606	607	609	611	612	33	.17
34	612	614	616	618	619	621	623	624	626	628	629	34	.18
35	629	631	633	634	636	638	639	641	643	644	646	35	.17
36	646	648	649	651	653	654	656	658	659	661	663	36	.17
37	663	664	666	668	669	671	673	674	676	677	679	37	.17
38	679	681	682	684	686	687	689	690	692	694	695	38	.17
39	695	697	698	700	702	703	705	706	708	710	711	39	.17
40	711	713	714	716	717	719	721	722	724	725	727	40	.16
41	727	728	730	732	733	735	736	738	739	741	743	41	.16
42	743	744	746	747	749	750	752	753	755	756	758	42	.15
43	758	760	761	763	764	766	767	769	770	772	774	43	.16
44	774	775	777	778	780	781	783	784	786	787	789	44	.15
45	789	790	792	794	795	797	798	800	801	803	804	45	.15
46	804	806	807	809	810	812	813	815	816	818	820	46	.15
47	820	821	823	824	826	827	829	830	832	833	835	47	.15
48	835	836	838	839	841	842	844	845	847	848	850	48	.15
49	850	852	853	855	856	858	859	861	862	864	865	49	.15
50	865	867	868	870	871	873	874	876	877	879	880	50	.15
51	880	882	883	885	886	888	890	891	893	894	896	51	.16
52	896	897	899	900	902	904	905	907	909	910	912	52	.16
53	912	914	915	917	919	920	922	924	926	927	929	53	.17
54	929	931	932	934	936	937	939	941	942	944	946	54	.17
55	946	948	949	951	953	954	956	958	959	961	963	55	.17
56	963	964	966	968	969	971	973	974	976	978	980	56	.17
57	980	981	983	985	986	988	990	991	993	995	996	57	.17
58	996	998	1000	1001	1003	1005	1006	1008	1010	1012	1013	58	.17
59	1013	1015	1017	1018	1020	1021	1023	1025	1026	1028	1030	59	.17

To interpolate between two printed values, add the increase in degrees per 0.01 m.v. (shown in the right hand column) for each 0.01 m.v. above the lower printed value.

Example: - 8.23 m. v. = - (8.20 + 0.03) m. v.
(Negative m. v.)
0.03 m. v. = $\frac{0.03}{0.01} \times 0.27^\circ = 0.81^\circ$
- 8.20 m. v. = - 134° C.
- 8.23 m. v. = - ($134^\circ + 0.81^\circ$) = - 134.81° C.

Example: 40.68 m. v. = 40.60 m. v. + 0.08 m. v.
(Positive m. v.)
0.08 m. v. = $\frac{0.08}{0.01} \times 0.16^\circ = 0.96^\circ$ C.
40.60 m. v. = 721° C.
40.68 m. v. = $721^\circ + 0.96^\circ = 721.96^\circ$ C.

Iron-Constantan Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

COLD JUNCTION 0° C.

TYPE I. C.

Deg. Cent.	0	100	200	300	400	500	600	700	800	900	1000	Deg. Cent.
MILLIVOLTS												
0	0.00	5.28	10.77	16.31	21.86	27.43	33.15	39.18	45.47	51.82	58.17	0
2	0.10	5.39	10.88	16.42	21.97	27.54	33.27	39.30	45.60	51.95	58.29	2
4	0.21	5.50	10.99	16.53	22.08	27.66	33.39	39.43	45.72	52.07	58.42	4
6	0.31	5.61	11.10	16.65	22.19	27.77	33.51	39.55	45.85	52.20	58.55	6
8	0.42	5.71	11.21	16.76	22.30	27.88	33.63	39.67	45.98	52.33	58.67	8
10	0.52	5.82	11.33	16.87	22.41	27.99	33.74	39.80	46.11	52.46	58.80	10
12	0.62	5.93	11.44	16.98	22.52	28.11	33.86	39.92	46.23	52.58	58.93	12
14	0.73	6.04	11.55	17.09	22.63	28.22	33.98	40.05	46.36	52.71	59.06	14
16	0.83	6.15	11.66	17.20	22.74	28.33	34.10	40.17	46.49	52.84	59.18	16
18	0.94	6.26	11.77	17.31	22.85	28.45	34.22	40.30	46.61	52.96	59.31	18
20	1.04	6.37	11.88	17.42	22.97	28.56	34.34	40.42	46.74	53.09	59.44	20
22	1.14	6.48	11.99	17.53	23.08	28.67	34.46	40.55	46.87	53.22	59.57	22
24	1.25	6.59	12.10	17.64	23.19	28.79	34.57	40.67	47.00	53.34	59.69	24
26	1.35	6.70	12.21	17.75	23.30	28.90	34.69	40.80	47.12	53.47	59.82	26
28	1.46	6.80	12.32	17.86	23.41	29.01	34.81	40.92	47.25	53.60	59.95	28
30	1.56	6.91	12.43	17.97	23.52	29.12	34.93	41.05	47.38	53.73	60.07	30
32	1.67	7.02	12.54	18.08	23.63	29.24	35.05	41.17	47.50	53.85	60.20	32
34	1.77	7.13	12.65	18.19	23.75	29.35	35.17	41.30	47.63	53.98	60.33	34
36	1.88	7.24	12.76	18.30	23.86	29.47	35.29	41.42	47.76	54.11	60.45	36
38	1.98	7.35	12.87	18.42	23.97	29.58	35.41	41.55	47.88	54.23	60.58	38
40	2.09	7.46	12.98	18.53	24.08	29.69	35.53	41.67	48.01	54.36	60.71	40
42	2.19	7.57	13.10	18.64	24.19	29.81	35.65	41.80	48.14	54.49	60.84	42
44	2.30	7.68	13.21	18.75	24.30	29.92	35.77	41.92	48.27	54.61	60.96	44
46	2.40	7.79	13.32	18.86	24.41	30.04	35.89	42.05	48.39	54.74	61.09	46
48	2.51	7.90	13.43	18.97	24.53	30.15	36.01	42.18	48.52	54.87	61.22	48
50	2.61	8.01	13.54	19.08	24.64	30.26	36.13	42.30	48.65	54.99	61.34	50
52	2.72	8.12	13.65	19.19	24.75	30.38	36.25	42.43	48.77	55.12	61.47	52
54	2.83	8.23	13.76	19.30	24.86	30.49	36.37	42.55	48.90	55.25	61.60	54
56	2.93	8.34	13.87	19.41	24.97	30.61	36.49	42.68	49.03	55.37	61.73	56
58	3.04	8.45	13.98	19.53	25.08	30.72	36.61	42.81	49.15	55.50	61.86	58
60	3.14	8.56	14.09	19.64	25.19	30.83	36.73	42.93	49.28	55.63	61.98	60
62	3.25	8.67	14.20	19.75	25.30	30.95	36.85	43.06	49.41	55.75	62.11	62
64	3.36	8.78	14.31	19.86	25.41	31.06	36.97	43.18	49.54	55.88	62.24	64
66	3.46	8.89	14.43	19.97	25.53	31.18	37.09	43.31	49.66	56.01	62.36	66
68	3.57	9.00	14.54	20.08	25.64	31.29	37.21	43.44	49.79	56.13	62.49	68
70	3.67	9.11	14.65	20.19	25.75	31.41	37.33	43.57	49.92	56.26	62.62	70
72	3.78	9.22	14.76	20.30	25.86	31.52	37.45	43.69	50.04	56.39	62.75	72
74	3.89	9.33	14.87	20.41	25.97	31.64	37.58	43.82	50.17	56.51	62.87	74
76	3.99	9.44	14.98	20.52	26.09	31.76	37.70	43.95	50.30	56.64	63.00	76
78	4.10	9.55	15.09	20.63	26.20	31.87	37.82	44.07	50.42	56.77	63.13	78
80	4.21	9.66	15.20	20.75	26.31	31.99	37.94	44.20	50.55	56.90	63.26	80
82	4.31	9.77	15.31	20.86	26.42	32.10	38.07	44.33	50.68	57.02	63.39	82
84	4.42	9.88	15.42	20.97	26.53	32.22	38.19	44.45	50.80	57.15	63.51	84
86	4.53	9.99	15.54	21.08	26.65	32.34	38.31	44.58	50.93	57.28	63.64	86
88	4.63	10.11	15.65	21.19	26.76	32.45	38.44	44.71	51.06	57.40	63.77	88
90	4.74	10.22	15.76	21.30	26.87	32.57	38.56	44.84	51.19	57.53	63.90	90
92	4.85	10.33	15.87	21.41	26.98	32.69	38.68	44.96	51.31	57.66	64.03	92
94	4.96	10.44	15.98	21.52	27.09	32.80	38.81	45.09	51.44	57.78	64.15	94
96	5.07	10.55	16.09	21.63	27.21	32.92	38.93	45.22	51.57	57.91	64.28	96
98	5.17	10.66	16.20	21.74	27.32	33.04	39.05	45.34	51.69	58.04	64.41	98
100	5.28	10.77	16.31	21.86	27.43	33.15	39.18	45.47	51.82	58.17	64.54	100
M. V. per °C.	0.053	0.055	0.055	0.056	0.056	0.057	0.060	0.063	0.064	0.064	0.064	M. V. per °C.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the printed value.

Example: $671^{\circ} = 670^{\circ} + 1^{\circ} = (37.33 + 0.06) \text{ m. v.} = 37.39 \text{ m. v.}$
 $81.5^{\circ} = 80^{\circ} + 1.5^{\circ} = (4.21 + 1.5 \times 0.063) \text{ m. v.} = 4.29 \text{ m. v.}$

Iron-Constantan Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE

COLD JUNCTION AT 0° C.

TYPE I. C.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Cent. per 0.01 M.V.
DEGREES CENTIGRADE													
0	0	2	4	6	8	10	12	13	15	17	19	0	.19
1	19	21	23	25	27	29	31	33	35	36	38	1	.19
2	38	40	42	44	46	48	50	52	54	55	57	2	.18
3	57	59	61	63	65	67	69	70	72	74	76	3	.19
4	76	78	80	82	84	86	87	89	91	93	95	4	.19
5	95	97	98	100	102	104	106	108	110	111	113	5	.18
6	113	115	117	119	121	122	124	126	128	130	132	6	.18
7	132	133	135	137	139	141	142	144	146	148	150	7	.18
8	150	152	154	155	157	159	161	163	164	166	168	8	.18
9	168	170	172	173	175	177	179	181	183	185	186	9	.18
10	186	188	190	192	193	195	197	199	201	202	204	10	.18
11	204	206	208	210	211	213	215	217	219	220	222	11	.18
12	222	224	226	228	229	231	233	235	237	238	240	12	.18
13	240	242	244	246	247	249	251	253	255	257	258	13	.18
14	258	260	262	264	266	267	269	271	273	275	276	14	.18
15	276	278	280	282	284	285	287	289	291	293	294	15	.18
16	294	296	298	300	302	303	305	307	309	311	312	16	.18
17	312	314	316	318	320	321	323	325	327	329	331	17	.18
18	331	332	334	336	338	340	341	343	345	347	349	18	.18
19	349	350	352	354	356	358	360	361	363	365	367	19	.18
20	367	368	370	372	374	376	377	379	381	383	385	20	.18
21	385	387	388	390	392	394	395	397	399	401	403	21	.18
22	403	404	406	408	410	412	413	415	417	419	421	22	.18
23	421	422	424	426	428	430	431	433	435	437	439	23	.18
24	439	440	442	444	446	448	449	451	453	455	457	24	.18
25	457	458	460	462	464	466	467	469	471	473	475	25	.18
26	475	476	478	480	482	483	485	487	489	491	492	26	.18
27	492	494	496	498	499	501	503	505	507	508	510	27	.18
28	510	512	514	515	517	519	521	523	524	526	528	28	.17
29	528	530	531	533	535	537	538	540	542	544	545	29	.18
30	545	547	549	551	552	554	556	558	559	561	563	30	.17
31	563	565	566	568	570	572	573	575	577	579	580	31	.17
32	580	582	584	586	587	589	591	592	594	596	597	32	.17
33	597	599	601	602	604	606	608	609	611	613	614	33	.17
34	614	616	618	619	621	623	624	626	628	629	631	34	.17
35	631	633	635	636	638	640	641	643	645	646	648	35	.17
36	648	650	651	653	655	656	658	660	661	663	665	36	.16
37	665	666	668	669	671	673	674	676	678	679	681	37	.16
38	681	683	684	686	687	689	691	692	694	695	697	38	.16
39	697	699	700	702	704	705	707	708	710	712	713	39	.16
40	713	715	716	718	720	721	723	724	726	728	729	40	.16
41	729	731	732	734	736	737	739	740	742	744	745	41	.16
42	745	747	748	750	752	753	755	756	758	760	761	42	.16
43	761	763	764	766	767	769	771	772	774	775	777	43	.16
44	777	778	780	782	783	785	786	788	789	791	793	44	.16
45	793	794	796	797	799	800	802	804	806	807	808	45	.16
46	808	810	812	813	815	816	818	819	821	823	824	46	.16
47	824	826	827	829	830	832	834	835	837	838	840	47	.16
48	840	841	843	845	846	848	849	851	853	854	856	48	.16
49	856	857	859	860	862	863	865	867	868	870	871	49	.16
50	871	873	874	876	878	879	881	882	884	886	887	50	.16
51	887	889	890	892	893	895	897	898	900	901	903	51	.16
52	903	904	906	908	909	911	912	914	915	917	919	52	.16
53	919	920	922	923	925	926	928	930	931	933	934	53	.16
54	934	936	937	939	941	942	944	945	947	949	950	54	.16
55	950	952	953	955	956	958	960	961	963	964	966	55	.16
56	966	967	969	971	972	974	975	977	979	980	982	56	.16
57	982	983	985	986	988	990	992	993	994	996	997	57	.16
58	997	999	1001	1002	1004	1005	1007	1008	1010	1012	1013	58	.16
59	1013	1015	1016	1018	1019	1021	1023	1024	1026	1027	1029	59	.16
60	1029	1030	1032	1034	1035	1037	1038	1040	1041	1043	1045	60	.16
61	1045	1046	1048	1049	1051	1052	1054	1056	1057	1059	1060	61	.16
62	1060	1062	1063	1065	1067	1068	1070	1071	1073	1074	1076	62	.16
63	1076	1078	1079	1081	1082	1084	1085	1087	1088	1090	1092	63	.16
64	1092	1093	1095	1096	1098	1099	1101	1103	1104	1106	1108	64	.16

To interpolate between two printed values, add the increase in degrees per 0.01 millivolt (shown in the right hand column) for each 0.01 millivolt above the lower printed value.

Example: 31.45 m. v. = 31.40 m. v. + 0.05 m. v.

$$0.05 \text{ m. v.} = \frac{0.05}{0.01} \times 0.17 = .85^{\circ}\text{C.}$$

$$31.40 \text{ m. v.} = 570^{\circ}\text{C.} \quad 31.45 \text{ m. v.} = 570^{\circ} + 0.85^{\circ} = 570.85^{\circ}\text{C.} \quad (571^{\circ}\text{C.})$$

Chromel-Alumel Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

COLD JUNCTION 0° C.

TYPE M. A.

Deg. Cent.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	Deg. Cent.
MILLIVOLTS															
0	0.00	4.10	8.13	12.21	16.39	20.64	24.90	29.14	33.31	37.36	41.31	45.14	48.85	52.41	0
2	0.08	4.18	8.21	12.29	16.48	20.73	24.99	29.22	33.39	37.44	41.39	45.22	48.92	52.48	2
4	0.16	4.26	8.29	12.37	16.56	20.81	25.07	29.31	33.47	37.52	41.46	45.29	48.99	52.55	4
6	0.24	4.35	8.37	12.46	16.65	20.90	25.16	29.39	33.55	37.60	41.54	45.37	49.07	52.62	6
8	0.32	4.43	8.45	12.54	16.73	20.98	25.24	29.47	33.63	37.68	41.62	45.44	49.14	52.69	8
10	0.40	4.51	8.53	12.62	16.82	21.07	25.33	29.56	33.72	37.76	41.70	45.52	49.21	52.76	10
12	0.48	4.60	8.61	12.71	16.90	21.15	25.41	29.64	33.80	37.84	41.78	45.59	49.29	52.83	12
14	0.56	4.68	8.69	12.79	16.98	21.24	25.50	29.73	33.88	37.92	41.85	45.67	49.36	52.90	14
16	0.64	4.76	8.77	12.87	17.07	21.32	25.58	29.81	33.96	38.00	41.93	45.74	49.43	52.97	16
18	0.72	4.84	8.85	12.96	17.15	21.41	25.67	29.89	34.04	38.08	42.01	45.82	49.50	53.04	18
20	0.80	4.92	8.93	13.04	17.24	21.49	25.76	29.98	34.12	38.16	42.08	45.89	49.57	53.10	20
22	0.88	5.01	9.02	13.12	17.32	21.58	25.84	30.06	34.21	38.24	42.16	45.97	49.65	53.17	22
24	0.96	5.09	9.10	13.20	17.41	21.66	25.93	30.15	34.29	38.32	42.24	46.04	49.72	53.24	24
26	1.04	5.17	9.18	13.29	17.49	21.75	26.01	30.23	34.37	38.40	42.32	46.12	49.79	53.31	26
28	1.12	5.25	9.26	13.37	17.58	21.83	26.10	30.31	34.45	38.48	42.39	46.19	49.86	53.38	28
30	1.20	5.33	9.34	13.45	17.66	21.92	26.18	30.40	34.53	38.56	42.47	46.27	49.93	53.45	30
32	1.28	5.41	9.42	13.54	17.75	22.00	26.26	30.48	34.61	38.64	42.55	46.34	50.01	53.52	32
34	1.36	5.49	9.50	13.62	17.88	22.09	26.35	30.57	34.70	38.72	42.62	46.42	50.08	53.59	34
36	1.44	5.57	9.58	13.70	17.91	22.17	26.43	30.65	34.78	38.80	42.70	46.49	50.15	53.66	36
38	1.53	5.65	9.66	13.79	18.00	22.26	26.52	30.73	34.86	38.88	42.78	46.57	50.22	53.72	38
40	1.61	5.73	9.75	13.87	18.08	22.34	26.60	30.82	34.94	38.96	42.86	46.64	50.29	53.79	40
42	1.69	5.81	9.83	13.96	18.17	22.43	26.69	30.90	35.02	39.04	42.93	46.71	50.36	53.86	42
44	1.77	5.89	9.91	14.04	18.25	22.51	26.77	30.98	35.10	39.11	43.01	46.79	50.43	53.93	44
46	1.85	5.97	9.99	14.12	18.34	22.60	26.86	31.07	35.18	39.19	43.09	46.86	50.51	54.00	46
48	1.94	6.05	10.07	14.21	18.42	22.68	26.94	31.15	35.27	39.27	43.16	46.94	50.58	54.07	48
50	2.02	6.13	10.15	14.29	18.51	22.77	27.03	31.23	35.35	39.35	43.24	47.01	50.65	54.13	50
52	2.10	6.21	10.23	14.37	18.59	22.85	27.11	31.32	35.43	39.43	43.32	47.09	50.72	54.20	52
54	2.18	6.29	10.32	14.46	18.68	22.94	27.19	31.40	35.51	39.51	43.39	47.16	50.79	54.27	54
56	2.27	6.37	10.40	14.54	18.76	23.02	27.28	31.49	35.59	39.59	43.47	47.23	50.86	54.34	56
58	2.35	6.45	10.48	14.63	18.85	23.11	27.36	31.57	35.67	39.67	43.55	47.31	50.93	54.41	58
60	2.43	6.53	10.56	14.71	18.93	23.20	27.45	31.65	35.75	39.75	43.62	47.38	51.00	54.47	60
62	2.51	6.61	10.64	14.79	19.02	23.28	27.53	31.74	35.83	39.82	43.70	47.46	51.07	54.54	62
64	2.60	6.69	10.73	14.88	19.10	23.37	27.62	31.82	35.91	39.90	43.78	47.53	51.14	54.61	64
66	2.68	6.77	10.81	14.96	19.19	23.45	27.70	31.90	35.99	39.98	43.85	47.60	51.22	54.68	66
68	2.76	6.85	10.89	15.04	19.27	23.54	27.79	31.98	36.08	40.06	43.93	47.68	51.29	54.75	68
70	2.85	6.93	10.97	15.13	19.36	23.62	27.87	32.07	36.16	40.14	44.00	47.75	51.36	54.81	70
72	2.93	7.01	11.05	15.21	19.44	23.71	27.96	32.15	36.24	40.22	44.08	47.82	51.43	54.88	72
74	3.01	7.09	11.14	15.30	19.53	23.79	28.04	32.23	36.32	40.29	44.16	47.90	51.50	54.95	74
76	3.10	7.17	11.22	15.38	19.61	23.88	28.12	32.32	36.40	40.37	44.23	47.97	51.57	55.01	76
78	3.18	7.25	11.30	15.46	19.70	23.96	28.21	32.40	36.48	40.45	44.31	48.04	51.64	55.08	78
80	3.26	7.33	11.38	15.55	19.79	24.05	28.29	32.48	36.56	40.53	44.38	48.12	51.71	55.15	80
82	3.35	7.41	11.47	15.63	19.87	24.13	28.38	32.56	36.64	40.61	44.46	48.19	51.78	55.21	82
84	3.43	7.49	11.55	15.72	19.96	24.22	28.46	32.65	36.72	40.68	44.54	48.26	51.85	55.28	84
86	3.51	7.57	11.63	15.80	20.04	24.30	28.55	32.73	36.80	40.76	44.61	48.34	51.92	55.35	86
88	3.60	7.65	11.71	15.89	20.13	24.39	28.63	32.81	36.88	40.84	44.69	48.41	51.99	55.41	88
90	3.68	7.73	11.80	15.97	20.21	24.48	28.72	32.89	36.96	40.92	44.76	48.48	52.06	55.48	90
92	3.76	7.81	11.88	16.06	20.30	24.56	28.80	32.98	37.04	41.00	44.84	48.56	52.13	55.55	92
94	3.85	7.89	11.96	16.14	20.38	24.65	28.88	33.06	37.12	41.07	44.92	48.63	52.20	55.61	94
96	3.93	7.97	12.04	16.22	20.47	24.73	28.97	33.14	37.20	41.15	44.99	48.70	52.27	55.68	96
98	4.01	8.05	12.13	16.31	20.55	24.82	29.05	33.22	37.28	41.23	45.07	48.78	52.34	55.74	98
100	4.10	8.13	12.21	16.39	20.64	24.90	29.14	33.31	37.36	41.31	45.14	48.85	52.41	55.81	100
M. V. per °C.	0.041	0.040	0.041	0.042	0.043	0.043	0.042	0.042	0.041	0.040	0.038	0.037	0.036	0.034	M. V. per °C.

To interpolate between two printed values, add the increase in millivoltage per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $851^{\circ} = 850^{\circ} + 1^{\circ} = (35.35 + 0.041) \text{ m. v.} = 35.39 \text{ m. v.}$
 $58.5^{\circ} = 58^{\circ} + .5^{\circ} = (2.35 + .5 \times .041) \text{ m. v.} = 2.37 \text{ m. v.}$

Chromel-Alumel Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE

COLD JUNCTION AT 0°C

TYPE M. A.

Millivolts	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	Millivolts	Deg. Cent. per 0.01 M.V.
DEGREES CENTIGRADE													
0	0	2	5	8	10	13	15	18	20	23	25	0	.25
1	25	28	30	33	35	37	40	42	45	47	50	1	.24
2	50	52	54	57	59	62	64	67	69	71	74	2	.24
3	74	76	79	81	83	86	88	91	93	95	98	3	.24
4	98	100	103	105	107	110	112	115	117	119	122	4	.24
5	122	124	127	129	132	134	137	139	142	144	147	5	.25
6	147	149	152	154	157	159	162	164	167	169	172	6	.25
7	172	174	177	179	182	184	187	189	192	194	197	7	.25
8	197	199	202	204	207	209	212	214	217	219	222	8	.25
9	222	224	227	229	232	234	236	239	241	244	246	9	.24
10	246	249	251	254	256	259	261	263	266	268	271	10	.24
11	271	273	276	278	280	283	285	288	290	293	295	11	.24
12	295	297	300	302	305	307	309	312	314	317	319	12	.24
13	319	322	324	326	329	331	333	336	338	341	343	13	.24
14	343	345	348	350	353	355	357	360	362	365	367	14	.24
15	367	369	372	374	376	379	381	384	386	388	391	15	.23
16	391	393	395	398	400	403	405	407	410	412	414	16	.24
17	414	417	419	421	424	426	429	431	433	436	438	17	.24
18	438	440	443	445	448	450	452	455	457	459	462	18	.23
19	462	464	466	469	471	473	476	478	480	483	485	19	.23
20	485	487	490	492	494	497	499	501	504	506	508	20	.23
21	508	511	513	516	518	520	523	525	527	530	532	21	.24
22	532	534	537	539	541	544	546	548	551	553	555	22	.23
23	555	558	560	562	565	567	569	572	574	577	579	23	.23
24	579	581	584	586	588	591	593	595	598	600	602	24	.23
25	602	605	607	609	612	614	616	619	621	623	626	25	.23
26	626	628	630	633	635	638	640	642	645	647	649	26	.24
27	649	652	654	657	659	661	664	666	668	671	673	27	.23
28	673	675	678	680	683	685	687	690	692	694	697	28	.24
29	697	699	701	704	706	709	711	713	716	718	721	29	.24
30	721	723	725	728	730	732	735	737	740	742	744	30	.24
31	744	747	749	752	754	756	759	761	764	766	768	31	.24
32	768	771	773	776	778	780	783	785	788	790	793	32	.24
33	793	795	797	800	802	805	807	810	812	815	817	33	.24
34	817	819	822	824	827	829	832	834	837	839	841	34	.24
35	841	844	846	849	851	854	856	859	861	864	866	35	.25
36	866	869	871	874	876	879	881	884	886	888	891	36	.25
37	891	893	896	898	901	903	906	908	911	913	916	37	.25
38	916	918	921	923	926	928	931	933	936	938	941	38	.25
39	941	944	946	949	951	954	956	959	961	964	967	39	.26
40	967	969	972	974	977	979	982	984	987	989	992	40	.26
41	992	994	997	999	1002	1005	1007	1010	1013	1015	1018	41	.26
42	1018	1020	1023	1026	1028	1031	1033	1036	1038	1041	1044	42	.26
43	1044	1046	1049	1052	1054	1057	1059	1062	1065	1067	1070	43	.26
44	1070	1073	1075	1078	1080	1083	1086	1088	1091	1094	1096	44	.26
45	1096	1099	1102	1104	1107	1110	1112	1115	1118	1120	1123	45	.27
46	1123	1126	1128	1131	1134	1136	1139	1142	1144	1147	1150	46	.27
47	1150	1152	1155	1158	1160	1163	1166	1169	1171	1174	1177	47	.28
48	1177	1180	1182	1185	1188	1190	1193	1196	1199	1201	1204	48	.27
49	1204	1207	1210	1212	1215	1218	1221	1224	1226	1229	1232	49	.28
50	1232	1235	1237	1240	1243	1246	1249	1252	1254	1257	1260	50	.28
51	1260	1263	1266	1268	1271	1274	1277	1280	1283	1285	1288	51	.28
52	1288	1291	1294	1297	1300	1303	1305	1308	1311	1314	1317	52	.29
53	1317	1320	1323	1326	1329	1332	1334	1337	1340	1343	1346	53	.29
54	1346	1349	1352	1355	1358	1361	1364	1367	1370	1373	1376	54	.29

To interpolate between two printed values, add the increase in degrees per 0.01 millivolt (shown in the right hand column) for each 0.01 millivolt above the lower printed value.

Example: Find degrees Cent. equal to 35.33 m. v.

$$35.33 - 35.30 = 0.03 \text{ m. v.} \quad \frac{0.03}{0.01} \times 0.26 = 0.78^\circ\text{C.}$$

$$35.30 \text{ m. v.} = 849^\circ\text{C. then } 35.33 \text{ m. v.} = 849^\circ + 0.78^\circ = 849.78^\circ\text{C. (850}^\circ\text{C.)}$$

Plat.-Plat. + 13% Rhodium Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

COLD JUNCTION 0° C.

TYPE Q. R.

Deg. Cent.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	Deg. Cent.
MILLIVOLTS																		
0	0.000	0.646	1.464	2.394	3.398	4.454	5.561	6.720	7.927	9.177	10.470	11.811	13.181	14.563	15.940	17.316	18.680	0
2	0.011	0.660	1.482	2.414	3.419	4.476	5.584	6.744	7.951	9.202	10.496	11.838	13.208	14.590	15.968	17.344	18.707	2
4	0.022	0.675	1.499	2.433	3.439	4.497	5.607	6.768	7.976	9.228	10.522	11.866	13.236	14.618	15.995	17.371	18.734	4
6	0.033	0.690	1.517	2.453	3.460	4.519	5.630	6.791	8.001	9.253	10.549	11.893	13.263	14.645	16.023	17.399	18.761	6
8	0.044	0.706	1.535	2.472	3.481	4.540	5.652	6.815	8.025	9.279	10.575	11.920	13.291	14.673	16.051	17.426	18.788	8
10	0.056	0.721	1.553	2.492	3.501	4.562	5.675	6.839	8.050	9.304	10.602	11.947	13.319	14.701	16.078	17.454	18.815	10
12	0.067	0.736	1.571	2.512	3.522	4.584	5.698	6.863	8.075	9.330	10.628	11.975	13.346	14.728	16.106	17.481	18.842	12
14	0.078	0.751	1.588	2.531	3.543	4.608	5.721	6.886	8.099	9.355	10.655	12.002	13.374	14.756	16.133	17.509	18.869	14
16	0.090	0.767	1.606	2.551	3.564	4.627	5.744	6.910	8.124	9.381	10.681	12.029	13.401	14.783	16.161	17.536	18.896	16
18	0.102	0.782	1.624	2.571	3.584	4.649	5.766	6.934	8.149	9.406	10.708	12.057	13.429	14.811	16.188	17.563	18.923	18
20	0.113	0.798	1.642	2.591	3.605	4.671	5.789	6.958	8.173	9.432	10.734	12.084	13.456	14.839	16.216	17.591	18.950	20
22	0.125	0.813	1.660	2.610	3.626	4.693	5.812	6.982	8.198	9.458	10.761	12.111	13.484	14.866	16.243	17.618	18.977	22
24	0.137	0.829	1.679	2.630	3.647	4.715	5.835	7.006	8.223	9.483	10.787	12.138	13.512	14.894	16.271	17.646	19.004	24
26	0.149	0.844	1.697	2.650	3.668	4.737	5.858	7.030	8.248	9.509	10.814	12.166	13.539	14.921	16.298	17.673	19.032	26
28	0.161	0.860	1.715	2.670	3.689	4.758	5.881	7.054	8.272	9.535	10.840	12.193	13.567	14.949	16.326	17.700	19.059	28
30	0.173	0.876	1.733	2.690	3.710	4.780	5.904	7.078	8.297	9.560	10.867	12.220	13.595	14.976	16.353	17.728	19.086	30
32	0.185	0.892	1.751	2.710	3.731	4.802	5.927	7.102	8.322	9.586	10.894	12.248	13.622	15.004	16.381	17.755	19.113	32
34	0.197	0.908	1.770	2.729	3.752	4.824	5.950	7.125	8.347	9.612	10.920	12.275	13.650	15.031	16.409	17.782	19.140	34
36	0.210	0.924	1.788	2.749	3.773	4.846	5.973	7.150	8.372	9.637	10.947	12.303	13.677	15.059	16.436	17.810	19.167	36
38	0.222	0.940	1.806	2.769	3.794	4.868	5.996	7.174	8.397	9.663	10.974	12.330	13.705	15.087	16.464	17.837	19.194	38
40	0.235	0.956	1.825	2.789	3.815	4.890	6.019	7.198	8.422	9.689	11.001	12.357	13.733	15.114	16.491	17.864	19.221	40
42	0.247	0.972	1.843	2.809	3.836	4.912	6.042	7.222	8.447	9.715	11.027	12.385	13.760	15.142	16.519	17.892	19.248	42
44	0.260	0.989	1.862	2.829	3.857	4.935	6.065	7.246	8.472	9.740	11.054	12.412	13.788	15.169	16.546	17.919	19.275	44
46	0.273	1.005	1.880	2.849	3.878	4.957	6.088	7.270	8.497	9.766	11.081	12.439	13.816	15.197	16.574	17.946	19.302	46
48	0.285	1.021	1.899	2.869	3.899	4.979	6.112	7.294	8.521	9.792	11.108	12.467	13.843	15.224	16.601	17.973	19.329	48
50	0.298	1.038	1.917	2.889	3.920	5.001	6.135	7.318	8.546	9.818	11.135	12.494	13.871	15.252	16.629	18.001	19.356	50
52	0.311	1.054	1.936	2.909	3.941	5.023	6.158	7.342	8.572	9.844	11.161	12.522	13.899	15.279	16.656	18.028	19.383	52
54	0.324	1.071	1.955	2.930	3.962	5.045	6.181	7.366	8.597	9.870	11.188	12.549	13.926	15.307	16.684	18.055	19.410	54
56	0.337	1.087	1.973	2.950	3.983	5.067	6.204	7.391	8.622	9.896	11.215	12.576	13.954	15.334	16.711	18.082	19.437	56
58	0.351	1.104	1.992	2.970	4.004	5.090	6.228	7.415	8.647	9.921	11.242	12.604	13.982	15.362	16.739	18.110	19.464	58
60	0.364	1.121	2.011	2.990	4.026	5.112	6.251	7.439	8.672	9.947	11.269	12.631	14.009	15.390	16.766	18.137	19.492	60
62	0.377	1.137	2.030	3.010	4.047	5.134	6.274	7.463	8.697	9.973	11.296	12.659	14.037	15.417	16.794	18.164	19.519	62
64	0.391	1.154	2.049	3.031	4.068	5.156	6.297	7.487	8.722	9.999	11.323	12.686	14.065	15.445	16.821	18.191	19.546	64
66	0.404	1.171	2.068	3.051	4.089	5.179	6.321	7.512	8.747	10.025	11.350	12.713	14.092	15.472	16.849	18.218	19.573	66
68	0.418	1.188	2.086	3.071	4.111	5.201	6.344	7.536	8.772	10.051	11.377	12.741	14.120	15.500	16.876	18.246	19.600	68
70	0.431	1.205	2.105	3.091	4.132	5.223	6.367	7.560	8.797	10.077	11.404	12.768	14.148	15.527	16.904	18.273	19.627	70
72	0.445	1.222	2.124	3.112	4.153	5.246	6.391	7.585	8.823	10.103	11.431	12.796	14.175	15.555	16.931	18.300	19.654	72
74	0.459	1.239	2.144	3.132	4.175	5.268	6.414	7.609	8.848	10.129	11.458	12.823	14.203	15.582	16.959	18.327	19.681	74
76	0.473	1.256	2.163	3.152	4.196	5.291	6.438	7.633	8.873	10.155	11.485	12.851	14.231	15.610	16.987	18.354	19.708	76
78	0.487	1.273	2.182	3.173	4.217	5.313	6.461	7.658	8.898	10.182	11.512	12.878	14.258	15.637	17.014	18.381	19.735	78
80	0.501	1.290	2.201	3.193	4.239	5.336	6.485	7.682	8.924	10.208	11.539	12.906	14.286	15.665	17.042	18.408	19.762	80
82	0.515	1.307	2.220	3.213	4.260	5.358	6.508	7.706	8.949	10.234	11.566	12.933	14.314	15.692	17.069	18.436	19.789	82
84	0.529	1.324	2.239	3.234	4.282	5.381	6.532	7.731	8.974	10.260	11.594	12.961	14.341	15.720	17.097	18.463	19.816	84
86	0.543	1.342	2.259	3.254	4.303	5.403	6.555	7.755	8.999	10.286	11.621	12.988	14.369	15.748	17.124	18.490	19.843	86
88	0.558	1.359	2.278	3.275	4.325	5.426	6.579	7.780	9.025	10.312	11.648	13.016	14.397	15.775	17.152	18.517	19.870	88
90	0.572	1.376	2.297	3.295	4.346	5.448	6.602	7.804	9.050	10.338	11.675	13.043	14.424	15.803	17.179	18.544	19.897	90
92	0.587	1.394	2.317	3.316	4.368	5.471	6.626	7.829	9.075	10.365	11.702	13.071	14.452	15.830	17.207	18.571	19.924	92
94	0.601	1.411	2.336	3.336	4.389	5.493	6.649	7.853	9.101	10.391	11.729	13.098	14.480	15.858	17.234	18.598	19.951	94
96	0.616	1.429	2.355	3.357	4.410	5.516	6.673	7.878	9.126	10.417	11.757	13.126	14.507	15.885	17.262	18.625	19.978	96
98	0.631	1.446	2.375	3.377	4.432	5.539	6.697	7.902	9.152	10.443	11.784	13.153	14.535	15.913	17.289	18.652	20.005	98
100	0.646	1.464	2.394	3.398	4.454	5.561	6.720	7.927	9.177	10.470	11.811	13.181	14.563	15.940	17.316	18.680	20.032	100
M. V. per °C.	0.0065	0.0082	0.0093	0.0100	0.0106	0.0111	0.0116	0.0121	0.0125	0.0129	0.0134	0.0137	0.0138	0.0138	0.0138	0.0136	0.0135	M. V. per °C.

To interpolate between two printed values, add the increase in millivolts per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $1451^{\circ} = 1450^{\circ} + 1^{\circ} = (18.829 + .0138) \text{ m. v.} = 18.843 \text{ m. v.}$
 $58.5^{\circ} = 58^{\circ} + .5^{\circ} = (.351 + .5 \times .0065) \text{ m. v.} = .354 \text{ m. v.}$

Plat.-Plat. + 13% Rhodium Thermocouple

COLD JUNCTION AT 0° C.

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE

TYPE Q. R.

Millivolts	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	Millivolts	Deg. Cent. per 0.005 M. V.
DEGREES CENTIGRADE																							
0	0	9	18	26	34	42	50	58	65	73	80	87	94	101	107	114	120	127	133	139	145	0	.73
1	145	152	158	164	169	175	181	187	193	198	204	210	215	221	226	232	237	243	248	253	259	1	.57
2	259	264	269	275	280	285	290	295	301	306	311	316	321	326	331	336	341	346	351	356	361	2	.52
3	361	366	371	376	381	386	390	395	400	405	410	415	419	424	429	434	439	443	448	453	458	3	.48
4	458	462	467	472	476	481	486	490	495	500	504	509	513	518	523	527	532	536	541	545	550	4	.47
5	550	554	559	563	568	572	577	581	586	590	595	599	603	608	612	617	621	625	630	634	638	5	.44
6	638	643	647	651	656	660	664	669	673	677	681	686	690	694	698	703	707	711	715	719	724	6	.43
7	724	728	732	736	740	744	749	753	757	761	765	769	773	777	781	786	790	794	798	802	806	7	.42
8	806	810	814	818	822	826	830	834	838	842	846	850	854	858	862	866	870	874	878	882	886	8	.40
9	886	890	894	898	902	906	910	914	918	921	925	929	933	937	941	945	949	953	956	960	964	9	.39
10	964	968	972	976	979	983	987	991	995	998	1002	1006	1010	1014	1017	1021	1025	1029	1032	1036	1040	10	.38
11	1040	1044	1047	1051	1055	1059	1062	1066	1070	1073	1077	1081	1084	1088	1092	1096	1099	1103	1107	1110	1114	11	.37
12	1114	1118	1121	1125	1129	1132	1136	1139	1143	1147	1150	1154	1158	1161	1165	1169	1172	1176	1180	1183	1187	12	.37
13	1187	1191	1194	1198	1201	1205	1209	1212	1216	1220	1223	1227	1230	1234	1238	1241	1245	1249	1252	1256	1259	13	.37
14	1259	1263	1267	1270	1274	1277	1281	1285	1288	1292	1295	1299	1303	1306	1310	1314	1317	1321	1324	1328	1332	14	.36
15	1332	1335	1339	1343	1346	1350	1353	1357	1361	1364	1368	1372	1375	1379	1383	1386	1390	1393	1397	1401	1404	15	.36
16	1404	1408	1412	1415	1419	1422	1426	1430	1433	1437	1441	1444	1448	1452	1455	1459	1462	1466	1470	1473	1477	16	.36
17	1477	1481	1484	1488	1492	1495	1499	1502	1506	1510	1513	1517	1521	1524	1528	1532	1535	1539	1543	1546	1550	17	.37
18	1550	1554	1557	1561	1565	1568	1572	1576	1579	1583	1587	1590	1594	1598	1602	1605	1609	1613	1616	1620	1624	18	.37
19	1624	1627	1631	1635	1638	1642	1646	1650	1653	1657	1661	1664	1668	1672	1675	1679	1683	1687	1690	1694	1698	19	.37

To interpolate between two printed values, add the increase per 0.005 millivolt (shown in the right hand column) for each 0.005 millivolt above the lower printed value.

Example: 11.47 m. v. = 11.45 m. v. + 0.02 m. v.

0.02 m. v. = $\frac{0.020}{0.005} \times 0.37 = 1.48^\circ\text{C.}$

11.45 m. v. = 1073°C. 11.47 m. v. = 1073° + 1.48° = 1074.48°C. (1075°C.)

Plat.-Plat. + 10% Rhodium Thermocouple

TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

COLD JUNCTION 0° C.

TYPE HERAEUS

Deg. Cent.	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	Deg. Cent.
MILLIVOLTS																			
0	0.000	0.643	1.433	2.316	3.251	4.219	5.222	6.260	7.330	8.434	9.569	10.736	11.924	13.120	14.312	15.498	16.674	17.841	0
2	0.011	0.658	1.453	2.334	3.270	4.239	5.243	6.281	7.352	8.456	9.592	10.759	11.948	13.144	14.336	15.521	16.699	17.864	2
4	0.022	0.672	1.470	2.352	3.289	4.258	5.263	6.302	7.374	8.479	9.615	10.783	11.972	13.168	14.360	15.545	16.721	17.887	4
6	0.033	0.687	1.487	2.370	3.308	4.278	5.284	6.323	7.396	8.501	9.638	10.807	11.995	13.192	14.383	15.569	16.744	17.911	6
8	0.045	0.702	1.504	2.389	3.327	4.298	5.304	6.344	7.417	8.523	9.661	10.830	12.019	13.216	14.407	15.592	16.768	17.934	8
10	0.056	0.717	1.521	2.407	3.346	4.317	5.325	6.366	7.439	8.546	9.684	10.854	12.043	13.240	14.431	15.616	16.791	17.957	10
12	0.067	0.732	1.538	2.425	3.365	4.337	5.345	6.387	7.461	8.568	9.707	10.878	12.067	13.264	14.455	15.639	16.815	17.980	12
14	0.079	0.747	1.555	2.444	3.384	4.357	5.366	6.408	7.483	8.591	9.730	10.901	12.091	13.288	14.479	15.663	16.838	18.004	14
16	0.090	0.762	1.572	2.462	3.404	4.377	5.386	6.429	7.505	8.613	9.754	10.925	12.115	13.311	14.502	15.687	16.861	18.027	16
18	0.102	0.777	1.589	2.480	3.423	4.397	5.407	6.450	7.527	8.636	9.777	10.949	12.139	13.335	14.526	15.710	16.885	18.050	18
20	0.114	0.792	1.606	2.499	3.442	4.416	5.428	6.471	7.548	8.658	9.800	10.973	12.163	13.359	14.550	15.734	16.908	18.073	20
22	0.126	0.807	1.623	2.517	3.461	4.436	5.448	6.493	7.570	8.681	9.823	10.996	12.187	13.383	14.574	15.757	16.932	.....	22
24	0.138	0.822	1.641	2.536	3.480	4.456	5.469	6.514	7.592	8.703	9.846	11.020	12.210	13.407	14.597	15.781	16.955	.....	24
26	0.150	0.837	1.658	2.554	3.499	4.476	5.489	6.535	7.614	8.726	9.869	11.044	12.234	13.431	14.621	15.805	16.978	.....	26
28	0.162	0.853	1.675	2.572	3.519	4.498	5.510	6.556	7.636	8.748	9.893	11.067	12.258	13.455	14.645	15.828	17.002	.....	28
30	0.174	0.868	1.692	2.591	3.538	4.516	5.531	6.578	7.658	8.771	9.916	11.091	12.282	13.478	14.669	15.852	17.025	.....	30
32	0.186	0.884	1.710	2.609	3.557	4.536	5.551	6.599	7.680	8.794	9.939	11.115	12.306	13.502	14.692	15.875	17.049	.....	32
34	0.198	0.899	1.727	2.628	3.576	4.556	5.572	6.620	7.702	8.816	9.962	11.139	12.330	13.526	14.716	15.899	17.072	.....	34
36	0.211	0.915	1.745	2.647	3.596	4.576	5.593	6.642	7.724	8.839	9.985	11.162	12.354	13.550	14.740	15.923	17.095	.....	36
38	0.223	0.930	1.762	2.665	3.615	4.596	5.613	6.663	7.746	8.861	10.009	11.186	12.378	13.574	14.764	15.946	17.119	.....	38
40	0.235	0.946	1.779	2.684	3.634	4.616	5.634	6.684	7.768	8.884	10.032	11.210	12.402	13.598	14.787	15.970	17.142	.....	40
42	0.248	0.962	1.797	2.703	3.653	4.636	5.655	6.706	7.790	8.907	10.055	11.234	12.426	13.621	14.811	15.993	17.165	.....	42
44	0.261	0.977	1.814	2.721	3.673	4.656	5.675	6.727	7.812	8.929	10.079	11.257	12.450	13.645	14.835	16.017	17.189	.....	44
46	0.273	0.993	1.832	2.740	3.692	4.676	5.696	6.748	7.834	8.952	10.102	11.281	12.474	13.669	14.859	16.040	17.212	.....	46
48	0.286	1.009	1.850	2.759	3.711	4.696	5.717	6.770	7.856	8.975	10.125	11.305	12.498	13.693	14.882	16.064	17.235	.....	48
50	0.299	1.025	1.867	2.777	3.731	4.716	5.737	6.791	7.878	8.997	10.148	11.329	12.522	13.717	14.906	16.087	17.259	.....	50
52	0.312	1.041	1.885	2.796	3.750	4.736	5.758	6.813	7.900	9.020	10.172	11.352	12.546	13.741	14.930	16.111	17.282	.....	52
54	0.325	1.057	1.903	2.815	3.770	4.756	5.779	6.834	7.922	9.043	10.195	11.376	12.570	13.765	14.953	16.135	17.305	.....	54
56	0.338	1.073	1.920	2.834	3.789	4.776	5.800	6.855	7.944	9.066	10.219	11.400	12.594	13.788	14.977	16.158	17.329	.....	56
58	0.351	1.089	1.938	2.852	3.808	4.796	5.821	6.877	7.966	9.088	10.242	11.424	12.617	13.812	15.001	16.182	17.352	.....	58
60	0.364	1.105	1.956	2.871	3.828	4.816	5.841	6.898	7.988	9.111	10.265	11.448	12.641	13.836	15.024	16.205	17.375	.....	60
62	0.378	1.121	1.973	2.890	3.847	4.837	5.862	6.920	8.011	9.134	10.289	11.471	12.665	13.860	15.048	16.229	17.399	.....	62
64	0.391	1.137	1.991	2.909	3.867	4.857	5.883	6.941	8.033	9.157	10.312	11.495	12.689	13.884	15.072	16.252	17.422	.....	64
66	0.405	1.154	2.009	2.928	3.886	4.877	5.904	6.963	8.055	9.180	10.336	11.519	12.713	13.907	15.096	16.276	17.445	.....	66
68	0.418	1.170	2.027	2.947	3.906	4.897	5.925	6.984	8.077	9.202	10.359	11.543	12.737	13.931	15.119	16.299	17.468	.....	68
70	0.432	1.186	2.045	2.966	3.925	4.917	5.946	7.006	8.099	9.225	10.383	11.567	12.761	13.955	15.143	16.322	17.492	.....	70
72	0.445	1.203	2.063	2.985	3.945	4.938	5.966	7.027	8.121	9.248	10.406	11.590	12.785	13.979	15.167	16.346	17.515	.....	72
74	0.459	1.219	2.081	3.004	3.964	4.958	5.937	7.049	8.144	9.271	10.430	11.614	12.809	14.003	15.190	16.369	17.538	.....	74
76	0.473	1.236	2.099	3.022	3.984	4.978	6.008	7.071	8.166	9.294	10.453	11.638	12.833	14.026	15.214	16.393	17.562	.....	76
78	0.487	1.252	2.117	3.041	4.003	4.998	6.029	7.092	8.188	9.317	10.477	11.662	12.857	14.050	15.237	16.416	17.585	.....	78
80	0.500	1.269	2.134	3.060	4.023	5.019	6.050	7.114	8.210	9.339	10.500	11.686	12.881	14.074	15.261	16.440	17.608	.....	80
82	0.514	1.285	2.152	3.079	4.042	5.039	6.071	7.135	8.233	9.362	10.524	11.709	12.905	14.098	15.285	16.463	17.631	.....	82
84	0.528	1.302	2.170	3.098	4.062	5.059	6.092	7.157	8.255	9.385	10.547	11.733	12.929	14.122	15.308	16.487	17.655	.....	84
86	0.542	1.318	2.189	3.117	4.081	5.080	6.113	7.179	8.277	9.408	10.571	11.757	12.953	14.145	15.332	16.510	17.678	.....	86
88	0.557	1.335	2.207	3.136	4.101	5.100	6.134	7.200	8.300	9.431	10.594	11.781	12.977	14.169	15.356	16.534	17.701	.....	88
90	0.571	1.352	2.225	3.155	4.121	5.120	6.155	7.222	8.322	9.454	10.618	11.805	13.001	14.193	15.379	16.557	17.724	.....	90
92	0.585	1.368	2.243	3.174	4.140	5.141	6.176	7.244	8.344	9.477	10.641	11.828	13.025	14.217	15.403	16.580	17.748	.....	92
94	0.600	1.385	2.261	3.193	4.160	5.161	6.197	7.265	8.367	9.500	10.665	11.852	13.048	14.241	15.427	16.604	17.771	.....	94
96	0.614	1.402	2.279	3.212	4.180	5.182	6.218	7.287	8.389	9.523	10.689	11.876	13.072	14.264	15.450	16.627	17.794	.....	96
98	0.629	1.419	2.297	3.232	4.199	5.202	6.239	7.309	8.411	9.546	10.712	11.900	13.096	14.288	15.474	16.651	17.817	.....	98
100	0.643	1.436	2.316	3.251	4.219	5.222	6.260	7.330	8.434	9.569	10.736	11.924	13.120	14.312	15.498	16.674	17.841	.....	100
M. V. per C.	0.0064	0.0079	0.0088	0.0094	0.0097	0.0100	0.0104	0.0107	0.0110	0.0114	0.0117	0.0119	0.0120	0.0119	0.0118	0.0117	0.0116	0.0115	M. V. per C.

To interpolate between two printed values, add the increase in millivoltage per degree (shown at bottom of each column) for each degree above the lower printed value.

Example: $851^{\circ} = 850^{\circ} + 1^{\circ} = (7.378 + 0.011) \text{ m. v.} = 7.889 \text{ m. v.}$
 $58.5^{\circ} = 58^{\circ} + .5^{\circ} = (.351 + .5 \times 0.0064) \text{ m. v.} = .354 \text{ m. v.}$

Plat.-Plat. + 10% Rhodium Thermocouple

TO CONVERT MILLIVOLTS TO DEGREES CENTIGRADE
COLD JUNCTION AT 0° C.
TYPE HER.

Millivolts	0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	Millivolts	Deg. Cent. per 0.005 M. V.
DEGREES CENTIGRADE																							
0	0	9	18	26	34	42	50	58	65	73	80	87	94	101	108	114	121	128	134	141	147	0	.73
1	147	153	159	166	172	178	184	190	196	202	208	213	219	225	231	237	242	248	254	259	265	1	.59
2	265	271	276	282	287	293	298	304	309	315	320	326	331	336	342	347	352	358	363	368	374	2	.54
3	374	379	384	389	395	400	405	410	416	421	426	431	436	442	447	452	457	462	467	473	478	3	.52
4	478	483	488	493	498	503	508	513	518	523	528	533	538	543	548	553	558	563	568	573	578	4	.51
5	578	583	588	593	598	603	608	612	617	622	627	632	637	642	646	651	656	661	666	670	675	5	.49
6	675	680	685	690	694	699	704	709	713	718	723	727	732	737	741	746	751	755	760	765	769	6	.47
7	769	774	779	783	788	793	797	802	806	811	816	820	825	829	834	838	843	847	852	857	861	7	.46
8	861	866	870	875	879	884	888	893	897	901	906	910	915	919	924	928	933	937	941	946	950	8	.44
9	950	955	959	963	968	972	977	981	985	990	994	998	1003	1007	1011	1016	1020	1024	1029	1033	1037	9	.44
10	1037	1042	1046	1050	1054	1059	1063	1067	1071	1076	1080	1084	1088	1093	1097	1101	1105	1110	1114	1118	1122	10	.43
11	1122	1127	1131	1135	1139	1143	1148	1152	1156	1160	1164	1169	1173	1177	1181	1185	1190	1194	1198	1202	1206	11	.42
12	1206	1211	1215	1219	1223	1227	1231	1236	1240	1244	1248	1252	1257	1261	1265	1269	1273	1277	1282	1286	1290	12	.42
13	1290	1294	1298	1302	1307	1311	1315	1319	1323	1328	1332	1336	1340	1344	1349	1353	1357	1361	1365	1370	1374	13	.42
14	1374	1378	1382	1386	1391	1395	1399	1403	1407	1412	1416	1420	1424	1428	1433	1437	1441	1445	1449	1454	1458	14	.42
15	1458	1462	1466	1471	1475	1479	1483	1488	1492	1496	1500	1504	1509	1513	1517	1521	1526	1530	1534	1538	1543	15	.43
16	1543	1547	1551	1555	1560	1564	1568	1572	1577	1581	1585	1589	1594	1598	1602	1607	1611	1615	1619	1624	1628	16	.43
17	1628	1632	1636	1641	1645	1649	1653	1658	1662	1666	1671	1675	1679	1684	1688	1692	1697	1701	1705	1709	1714	17	.43

To interpolate between two printed values, add the increase in degrees per 0.005 millivolt (shown in the right hand column) for each 0.005 millivolt above the lower printed value.

Example: 12.52 m. v. = 12.50 + 0.02 m. v.

$$0.02 \text{ m. v.} = \frac{0.020}{0.005} \times 0.42 = 1.68^\circ \text{C.}$$
12.50 m. v. = 1248°C. 12.52 m. v. = 1248° + 1.68° = 1249.68°C. (1250°C.)

INSTRUCTIONS FOR BROWN INSTRUMENTS AND ACCESSORIES

SECTION 9112

(Issue 1, 6-1-38)

Brown Nickel Resistance Thermometer Bulb Type "A"

TEMPERATURE-RESISTANCE EQUIVALENTS

DEGREES FAHRENHEIT

DEGS. FAHR.	-100	-0	+0	+100	+200	DEGS. FAHR.
OHMS						
0	350.0	466.1	466.1	600.2	751.9	0
5	344.7	459.8	472.4	607.3	759.9	5
10	339.4	453.5	478.8	614.5	768.0	10
15	334.1	447.3	485.3	621.7	776.1	15
20	328.9	441.2	491.8	629.0	784.4	20
25	323.7	435.1	498.3	636.3	792.7	25
30	318.6	429.0	504.9	643.7	801.0	30
35	313.4	423.0	511.5	651.2	809.4	35
40	308.3	417.1	518.2	658.7	817.9	40
45	303.2	411.2	524.8	666.2	826.4	45
50	298.1	405.4	531.5	673.8	835.0	50
55	.....	399.6	538.3	681.4	843.7	55
60	.....	393.9	545.0	689.0	852.5	60
65	.....	388.3	551.8	696.7	861.3	65
70	.....	382.7	558.6	704.5	870.2	70
75	.....	377.1	565.4	712.3	879.1	75
80	.....	371.6	572.3	720.1	888.1	80
85	.....	366.1	579.2	728.0	897.2	85
90	.....	360.7	586.2	735.9	906.4	90
95	.....	355.3	593.2	743.9	915.6	95
100	.....	350.0	600.2	751.9	924.9	100

DEGREES CENTIGRADE

DEGS. CENT.	-0	+0	+100	DEGS. CENT.
OHMS				
0	507.5	507.5	771.2	0
5	495.7	519.5	786.0	5
10	483.9	531.5	801.0	10
15	472.4	543.7	816.2	15
20	461.0	555.9	831.6	20
25	449.8	568.2	847.2	25
30	438.7	580.6	863.1	30
35	427.8	593.2	879.1	35
40	417.1	605.9	895.4	40
45	406.5	618.8	911.9	45
50	396.1	631.9	928.6	50
55	385.8	645.2	.....	55
60	375.7	658.7	.....	60
65	365.8	672.2	.....	65
70	356.0	686.0	.....	70
75	346.4	699.8	.....	75
80	336.9	713.8	.....	80
85	327.6	728.0	.....	85
90	318.4	742.3	.....	90
95	309.4	756.7	.....	95
100	300.6	771.2	.....	100

SECTION 1046
Issue 3TEMPERATURE - MILLIVOLT EQUIVALENTS
FOR THE BROWN RADIAMATIC

TABLES

A. Fahrenheit-Centigrade Conversion Table	Page 2
B. Intermediate Range Radiamatic Type RI - To Convert Degrees Fahrenheit to Millivolts	Page 3
C. High Range Radiamatic Type RH - To Convert Degrees Fahrenheit to Millivolts	Page 4
D. Intermediate Range Radiamatic Type RI - To Convert Degrees Centigrade to Millivolts	Page 5
E. High Range Radiamatic Type RH - To Convert Degrees Centigrade to Millivolts	Page 6

THE BROWN INSTRUMENT CO.

PHILADELPHIA, PA., U. S. A.

Conversion of Centigrade and Fahrenheit Scales

For temperatures above 0° C.

For temperatures above 0° C.

Temp. °C.	0	1	2	3	4	5	6	7	8	9	Temp. °C.	0	1	2	3	4	5	6	7	8	9
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2	900	1652.0	1653.9	1655.8	1657.7	1659.6	1661.5	1663.4	1665.3	1667.2	1669.1
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2	910	1670.0	1671.8	1673.6	1675.4	1677.2	1679.0	1680.8	1682.6	1684.4	1686.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2	920	1688.0	1689.8	1691.6	1693.4	1695.2	1697.0	1698.8	1700.6	1702.4	1704.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2	930	1706.0	1707.8	1709.6	1711.4	1713.2	1715.0	1716.8	1718.6	1720.4	1722.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2	940	1724.0	1725.8	1727.6	1729.4	1731.2	1733.0	1734.8	1736.6	1738.4	1740.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2	950	1742.0	1743.8	1745.6	1747.4	1749.2	1751.0	1752.8	1754.6	1756.4	1758.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2	960	1760.0	1761.8	1763.6	1765.4	1767.2	1769.0	1770.8	1772.6	1774.4	1776.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2	970	1778.0	1779.8	1781.6	1783.4	1785.2	1787.0	1788.8	1790.6	1792.4	1794.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2	980	1796.0	1797.8	1799.6	1801.4	1803.2	1805.0	1806.8	1808.6	1810.4	1812.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2	990	1814.0	1815.8	1817.6	1819.4	1821.2	1823.0	1824.8	1826.6	1828.4	1830.2
100	212.0	213.8	215.6	217.4	219.2	221.0	222.8	224.6	226.4	228.2	1000	1832.0	1833.8	1835.6	1837.4	1839.2	1841.0	1842.8	1844.6	1846.4	1848.2
110	230.0	231.8	233.6	235.4	237.2	239.0	240.8	242.6	244.4	246.2	1010	1850.0	1851.8	1853.6	1855.4	1857.2	1859.0	1860.8	1862.6	1864.4	1866.2
120	248.0	249.8	251.6	253.4	255.2	257.0	258.8	260.6	262.4	264.2	1020	1868.0	1869.8	1871.6	1873.4	1875.2	1877.0	1878.8	1880.6	1882.4	1884.2
130	266.0	267.8	269.6	271.4	273.2	275.0	276.8	278.6	280.4	282.2	1030	1886.0	1887.8	1889.6	1891.4	1893.2	1895.0	1896.8	1898.6	1900.4	1902.2
140	284.0	285.8	287.6	289.4	291.2	293.0	294.8	296.6	298.4	300.2	1040	1904.0	1905.8	1907.6	1909.4	1911.2	1913.0	1914.8	1916.6	1918.4	1920.2
150	302.0	303.8	305.6	307.4	309.2	311.0	312.8	314.6	316.4	318.2	1050	1922.0	1923.8	1925.6	1927.4	1929.2	1931.0	1932.8	1934.6	1936.4	1938.2
160	320.0	321.8	323.6	325.4	327.2	329.0	330.8	332.6	334.4	336.2	1060	1940.0	1941.8	1943.6	1945.4	1947.2	1949.0	1950.8	1952.6	1954.4	1956.2
170	338.0	339.8	341.6	343.4	345.2	347.0	348.8	350.6	352.4	354.2	1070	1958.0	1959.8	1961.6	1963.4	1965.2	1967.0	1968.8	1970.6	1972.4	1974.2
180	356.0	357.8	359.6	361.4	363.2	365.0	366.8	368.6	370.4	372.2	1080	1976.0	1977.8	1979.6	1981.4	1983.2	1985.0	1986.8	1988.6	1990.4	1992.2
190	374.0	375.8	377.6	379.4	381.2	383.0	384.8	386.6	388.4	390.2	1090	1994.0	1995.8	1997.6	1999.4	2001.2	2003.0	2004.8	2006.6	2008.4	2010.2
200	392.0	393.8	395.6	397.4	399.2	401.0	402.8	404.6	406.4	408.2	1100	2012.0	2013.8	2015.6	2017.4	2019.2	2021.0	2022.8	2024.6	2026.4	2028.2
210	410.0	411.8	413.6	415.4	417.2	419.0	420.8	422.6	424.4	426.2	1110	2030.0	2031.8	2033.6	2035.4	2037.2	2039.0	2040.8	2042.6	2044.4	2046.2
220	428.0	429.8	431.6	433.4	435.2	437.0	438.8	440.6	442.4	444.2	1120	2048.0	2049.8	2051.6	2053.4	2055.2	2057.0	2058.8	2060.6	2062.4	2064.2
230	446.0	447.8	449.6	451.4	453.2	455.0	456.8	458.6	460.4	462.2	1130	2066.0	2067.8	2069.6	2071.4	2073.2	2075.0	2076.8	2078.6	2080.4	2082.2
240	464.0	465.8	467.6	469.4	471.2	473.0	474.8	476.6	478.4	480.2	1140	2084.0	2085.8	2087.6	2089.4	2091.2	2093.0	2094.8	2096.6	2098.4	2100.2
250	482.0	483.8	485.6	487.4	489.2	491.0	492.8	494.6	496.4	498.2	1150	2102.0	2103.8	2105.6	2107.4	2109.2	2111.0	2112.8	2114.6	2116.4	2118.2
260	500.0	501.8	503.6	505.4	507.2	509.0	510.8	512.6	514.4	516.2	1160	2120.0	2121.8	2123.6	2125.4	2127.2	2129.0	2130.8	2132.6	2134.4	2136.2
270	518.0	519.8	521.6	523.4	525.2	527.0	528.8	530.6	532.4	534.2	1170	2138.0	2139.8	2141.6	2143.4	2145.2	2147.0	2148.8	2150.6	2152.4	2154.2
280	536.0	537.8	539.6	541.4	543.2	545.0	546.8	548.6	550.4	552.2	1180	2156.0	2157.8	2159.6	2161.4	2163.2	2165.0	2166.8	2168.6	2170.4	2172.2
290	554.0	555.8	557.6	559.4	561.2	563.0	564.8	566.6	568.4	570.2	1190	2174.0	2175.8	2177.6	2179.4	2181.2	2183.0	2184.8	2186.6	2188.4	2190.2
300	572.0	573.8	575.6	577.4	579.2	581.0	582.8	584.6	586.4	588.2	1200	2192.0	2193.8	2195.6	2197.4	2199.2	2201.0	2202.8	2204.6	2206.4	2208.2
310	590.0	591.8	593.6	595.4	597.2	599.0	600.8	602.6	604.4	606.2	1210	2210.0	2211.8	2213.6	2215.4	2217.2	2219.0	2220.8	2222.6	2224.4	2226.2
320	608.0	609.8	611.6	613.4	615.2	617.0	618.8	620.6	622.4	624.2	1220	2228.0	2229.8	2231.6	2233.4	2235.2	2237.0	2238.8	2240.6	2242.4	2244.2
330	626.0	627.8	629.6	631.4	633.2	635.0	636.8	638.6	640.4	642.2	1230	2246.0	2247.8	2249.6	2251.4	2253.2	2255.0	2256.8	2258.6	2260.4	2262.2
340	644.0	645.8	647.6	649.4	651.2	653.0	654.8	656.6	658.4	660.2	1240	2264.0	2265.8	2267.6	2269.4	2271.2	2273.0	2274.8	2276.6	2278.4	2280.2
350	662.0	663.8	665.6	667.4	669.2	671.0	672.8	674.6	676.4	678.2	1250	2282.0	2283.8	2285.6	2287.4	2289.2	2291.0	2292.8	2294.6	2296.4	2298.2
360	680.0	681.8	683.6	685.4	687.2	689.0	690.8	692.6	694.4	696.2	1260	2300.0	2301.8	2303.6	2305.4	2307.2	2309.0	2310.8	2312.6	2314.4	2316.2
370	698.0	699.8	701.6	703.4	705.2	707.0	708.8	710.6	712.4	714.2	1270	2318.0	2319.8	2321.6	2323.4	2325.2	2327.0	2328.8	2330.6	2332.4	2334.2
380	716.0	717.8	719.6	721.4	723.2	725.0	726.8	728.6	730.4	732.2	1280	2336.0	2337.8	2339.6	2341.4	2343.2	2345.0	2346.8	2348.6	2350.4	2352.2
390	734.0	735.8	737.6	739.4	741.2	743.0	744.8	746.6	748.4	750.2	1290	2354.0	2355.8	2357.6	2359.4	2361.2	2363.0	2364.8	2366.6	2368.4	2370.2
400	752.0	753.8	755.6	757.4	759.2	761.0	762.8	764.6	766.4	768.2	1300	2372.0	2373.8	2375.6	2377.4	2379.2	2381.0	2382.8	2384.6	2386.4	2388.2
410	770.0	771.8	773.6	775.4	777.2	779.0	780.8	782.6	784.4	786.2	1310	2390.0	2391.8	2393.6	2395.4	2397.2	2399.0	2400.8	2402.6	2404.4	2406.2
420	788.0	789.8	791.6	793.4	795.2	797.0	798.8	800.6	802.4	804.2	1320	2408.0	2409.8	2411.6	2413.4	2415.2	2417.0	2418.8	2420.6	2422.4	2424.2
430	806.0	807.8	809.6	811.4	813.2	815.0	816.8	818.6	820.4	822.2	1330	2426.0	2427.8	2429.6	2431.4	2433.2	2435.0	2436.8	2438.6	2440.4	2442.2
440	824.0	825.8	827.6	829.4	831.2	833.0	834.8	836.6	838.4	840.2	1340	2444.0	2445.8	2447.6	2449.4	2451.2	2453.0	2454.8	2456.6	2458.4	2460.2
450	842.0	843.8	845.6	847.4	849.2	851.0	852.8	854.6	856.4	858.2	1350	2462.0	2463.8	2465.6	2467.4	2469.2	2471.0	2472.8	2474.6	2476.4	2478.2
460	860.0	861.8	863.6	865.4	867.2	869.0	870.8	872.6	874.4	876.2	1360	2480.0	2481.8	2483.6	2485.4	2487.2	2489.0	2490.8	2492.6	2494.4	2496.2
470	878.0	879.8	881.6	883.4	885.2	887.0	888.8	890.6	892.4	894.2	1370	2498.0	2499.8	2501.6	2503.4	2505.2	2507.0	2508.8	2510.6	2512.4	2514.2
480	896.0	897.8	899.6	901.4	903.2	905.0	906.8	908.6	910.4	912.2	1380	2516.0	2517.8	2519.6	2521.4	2523.2	2525.0	2526.8	2528.6	2530.4	2532.2
490	914.0	915.8	917.6	919.4	921.2	923.0	924.8	926.6	928.4	930.2	1390	2534.0	2535.8	2537.6	2539.4	2541.2	2543.0	2544.8	2546.6	2548.4	2550.2
500	932.0	933.8	935.6	937.4	939.2	941.0	942.8	944.6	946.4	948.2	1400	2552.0	2553.8	2555.6	2557.4	2559.2	2561.0	2562.8	2564.6	2566.4	2568.2
510	950.0	951.8	953.6	955.4	957.2	959.0	960.8	962.6	964.4	966.2	1410	2570.0	2571.8	2573.6	257						

B. TYPE RI INTERMEDIATE RANGE RADIAMATIC (FUSED SILICA LENS) TO CON-
VERT DEGREES FAHRENHEIT TO MILLIVOLTS

Degs. Fahr.	700	800	900	1000	1100	1200	1300	1400	1500	Degs. Fahr.
MILLIVOLTS										
0	0.12	0.21	0.33	0.50	0.76	1.11	1.57	2.16	2.90	0
10				0.52	0.79	1.15	1.62	2.23	2.98	10
20				0.54	0.82	1.19	1.67	2.30	3.07	20
30				0.56	0.85	1.23	1.73	2.37	3.16	30
40				0.59	0.88	1.27	1.79	2.44	3.25	40
50	0.16	0.27	0.41	0.62	0.91	1.32	1.85	2.51	3.34	50
60				0.65	0.95	1.37	1.91	2.58	3.43	60
70				0.67	0.99	1.42	1.97	2.66	3.53	70
80				0.70	1.03	1.47	2.03	2.74	3.63	80
90				0.73	1.07	1.52	2.09	2.82	3.73	90
100	0.21	0.33	0.50	0.76	1.11	1.57	2.16	2.90	3.83	100

Degs. Fahr.	1600	1700	1800	1900	2000	2100	2200	2300	2400	Degs. Fahr.
MILLIVOLTS										
0	3.83	4.93	6.25	7.82	9.65	11.76	14.19	16.97	20.11	0
10	3.93	5.05	6.40	7.99	9.85	11.99	14.45	17.26	20.44	10
20	4.03	5.17	6.55	8.16	10.05	12.23	14.71	17.56	20.78	20
30	4.14	5.30	6.70	8.34	10.25	12.47	14.98	17.87	21.12	30
40	4.25	5.43	6.85	8.52	10.46	12.71	15.25	18.18	21.47	40
50	4.36	5.56	7.00	8.70	10.67	12.95	15.53	18.50	21.82	50
60	4.47	5.69	7.16	8.89	10.88	13.19	15.81	18.82	22.18	60
70	4.58	5.82	7.32	9.08	11.10	13.44	16.10	19.14	22.54	70
80	4.69	5.96	7.48	9.27	11.32	13.69	16.39	19.46	22.90	80
90	4.81	6.10	7.65	9.46	11.54	13.94	16.68	19.78	23.26	90
100	4.93	6.25	7.82	9.65	11.76	14.19	16.97	20.11	23.63	100

Section 1046

Page No. 4

C. TYPE RH HIGH RANGE RADIAMATIC (PYREX LENS) TO CONVERT DEGREES
FAHRENHEIT TO MILLIVOLTS

Degs. Fahr.	700	800	900	1000	1100	1200	1300	1400	1500	Degs. Fahr.
MILLIVOLTS										
0	0.03	0.06	0.11	0.17	0.28	0.44	0.67	0.99	1.42	0
10						0.46	0.70	1.02	1.47	10
20						0.48	0.73	1.06	1.52	20
30						0.50	0.78	1.10	1.57	30
40						0.52	0.79	1.14	1.62	40
50	0.04	0.08	0.14	0.21	0.36	0.54	0.82	1.18	1.67	50
60						0.56	0.85	1.22	1.73	60
70						0.58	0.88	1.27	1.79	70
80						0.61	0.92	1.32	1.85	80
90						0.64	0.96	1.37	1.91	90
100	0.06	0.11	0.17	0.28	0.44	0.67	0.99	1.42	1.97	100

Degs. Fahr.	1600	1700	1800	1900	2000	2100	2200	2300	2400	Degs. Fahr.
MILLIVOLTS										
0	1.97	2.66	3.49	4.51	5.74	7.20	8.95	10.99	13.35	0
10	2.03	2.74	3.59	4.62	5.88	7.36	9.14	11.21	13.60	10
20	2.09	2.83	3.69	4.74	6.02	7.53	9.33	11.44	13.85	20
30	2.16	2.90	3.79	4.86	6.16	7.70	9.53	11.67	14.11	30
40	2.23	2.98	3.89	4.98	6.30	7.87	9.73	11.91	14.37	40
50	2.30	3.06	3.99	5.10	6.44	8.05	9.93	12.15	14.64	50
60	2.37	3.14	4.09	5.22	6.59	8.23	10.14	12.39	14.91	60
70	2.44	3.22	4.19	5.34	6.74	8.41	10.35	12.63	15.18	70
80	2.51	3.31	4.29	5.47	6.89	8.59	10.56	12.87	15.46	80
90	2.58	3.40	4.40	5.60	7.04	8.77	10.77	13.11	15.74	90
100	2.66	3.49	4.51	5.74	7.20	8.95	10.99	13.35	16.03	100

Degs. Fahr.	2500	2600	2700	2800	2900	3000	3100	3200	3300	Degs. Fahr.
MILLIVOLTS										
0	16.03	19.08	22.48	26.26	30.43	34.98	39.96	45.34	51.02	0
10	16.32	19.40	22.84	26.66	30.86	35.47	40.48	45.90	51.61	10
20	16.62	19.73	23.21	27.06	31.30	35.96	41.00	46.46	52.20	20
30	16.92	20.06	23.58	27.46	31.76	36.45	41.53	47.02	52.80	30
40	17.22	20.40	23.95	27.87	32.20	36.94	42.06	47.58	53.41	40
50	17.52	20.74	24.33	28.29	32.64	37.44	42.60	48.15	54.02	50
60	17.82	21.08	24.71	28.71	33.09	37.94	43.14	48.72	54.64	60
70	18.13	21.42	25.09	29.14	33.55	38.44	43.69	49.29	55.26	70
80	18.44	21.77	25.48	29.57	34.02	38.94	44.24	49.86	55.88	80
90	18.76	22.12	25.87	30.00	34.50	39.45	44.79	50.44	56.50	90
100	19.08	22.48	26.26	30.43	34.98	39.96	45.34	51.02	57.12	100

D. TYPE RI INTERMEDIATE RANGE RADIAMATIC (FUSED SILICA LENS) TO CONVERT DEGREES CENTIGRADE TO MILLIVOLTS

Degs. Cent.	400	500	600	700	800	Degs. Cent.
MILLIVOLTS						
0	0.16	0.38	0.79	1.53	2.69	0
10		0.41	0.85	1.62	2.83	10
20	0.20	0.44	0.91	1.72	2.97	20
30		0.47	0.97	1.82	3.13	30
40	0.24	0.51	1.04	1.93	3.29	40
50		0.55	1.11	2.04	3.45	50
60	0.28	0.59	1.19	2.16	3.63	60
70		0.64	1.27	2.28	3.81	70
80	0.33	0.69	1.35	2.41	3.99	80
90		0.74	1.44	2.55	4.19	90
100	0.38	0.79	1.53	2.69	4.39	100

Degs. Cent.	900	1000	1100	1200	1300	Degs. Cent.
MILLIVOLTS						
0	4.39	6.72	9.88	13.99	19.20	0
10	4.59	7.00	10.25	14.46	19.78	10
20	4.79	7.29	10.63	14.94	20.37	20
30	5.00	7.59	11.01	15.44	20.99	30
40	5.22	7.89	11.41	15.94	21.62	40
50	5.46	8.20	11.81	16.45	22.26	50
60	5.70	8.52	12.23	16.97	22.90	60
70	5.94	8.84	12.66	17.51	23.56	70
80	6.19	9.18	13.10	18.07	24.24	80
90	6.45	9.52	13.54	18.63	24.94	90
100	6.72	9.88	13.99	19.20	25.64	100

Section 1046

Page No. 6

E. TYPE RH HIGH RANGE RADIAMATIC (PYREX LENS) TO CONVERT DEGREES
CENTIGRADE TO MILLIVOLTS

Degs. Cent.	400	500	600	700	800	900	1000	Degs. Cent.
MILLIVOLTS								
0	0.04	0.13	0.29	0.65	1.29	2.31	3.81	0
10		0.14	0.32	0.70	1.37	2.43	3.99	10
20	0.05	0.15	0.35	0.75	1.46	2.57	4.17	20
30		0.16	0.38	0.81	1.55	2.71	4.35	30
40	0.07	0.17	0.41	0.87	1.64	2.85	4.55	40
50		0.19	0.44	0.93	1.74	2.99	4.77	50
60	0.09	0.21	0.48	0.99	1.85	3.14	4.99	60
70		0.23	0.52	1.06	1.96	3.30	5.21	70
80	0.11	0.25	0.56	1.13	2.07	3.46	5.43	80
90		0.27	0.60	1.21	2.19	3.63	5.65	90
100	0.13	0.29	0.65	1.29	2.31	3.81	5.89	100

Degs. Cent.	1100	1200	1300	1400	1500	1600	1700	Degs. Cent.
MILLIVOLTS								
0	5.89	8.79	12.66	17.57	23.66	30.95	39.54	0
10	6.14	9.13	13.10	18.13	24.34	31.74	40.48	10
20	6.40	9.49	13.55	18.70	25.02	32.54	41.43	20
30	6.67	9.85	14.01	19.28	25.71	33.37	42.39	30
40	6.95	10.22	14.49	19.86	26.41	34.22	43.36	40
50	7.24	10.60	14.97	20.46	27.13	35.08	44.34	50
60	7.54	10.99	15.47	21.08	27.87	35.94	45.34	60
70	7.84	11.40	15.98	21.70	28.63	36.82	46.34	70
80	8.15	11.82	16.50	22.34	29.39	37.71	47.36	80
90	8.47	12.24	17.03	22.99	30.17	38.62	48.38	90
100	8.79	12.66	17.57	23.66	30.95	39.54	49.40	100

